KREONET and Korean NREN status and evolution

April 17, 2024

Buseung Cho

Director of KREONET Center
KISTI

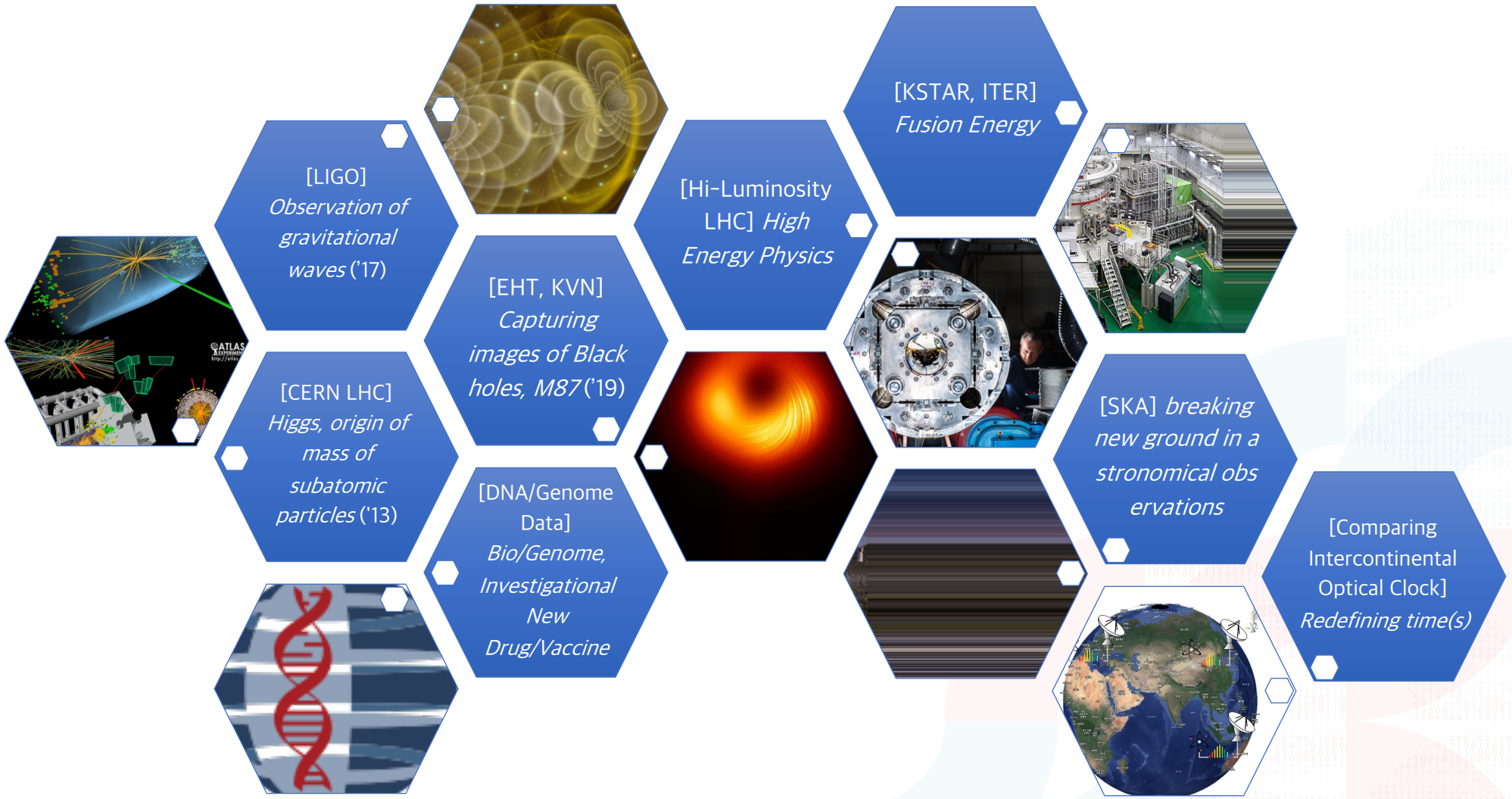
S&T Infra,
Changing the world with Data KiSTi

KREONET

Contents

- KREONET/KREONet2, Science and Research Networks in Korea
- LHCOPN, LHCONE and HEP Network of KREONET
- KREONET Developments and Applications
- Summary

KREONET/KREONet2 enabling Science Discovery



Big science, Data Intensive Science, Interdisciplinary research

KREONET/KREONet2, national science and research network

KREONET/KREONet2 (AS1237/ AS17579)

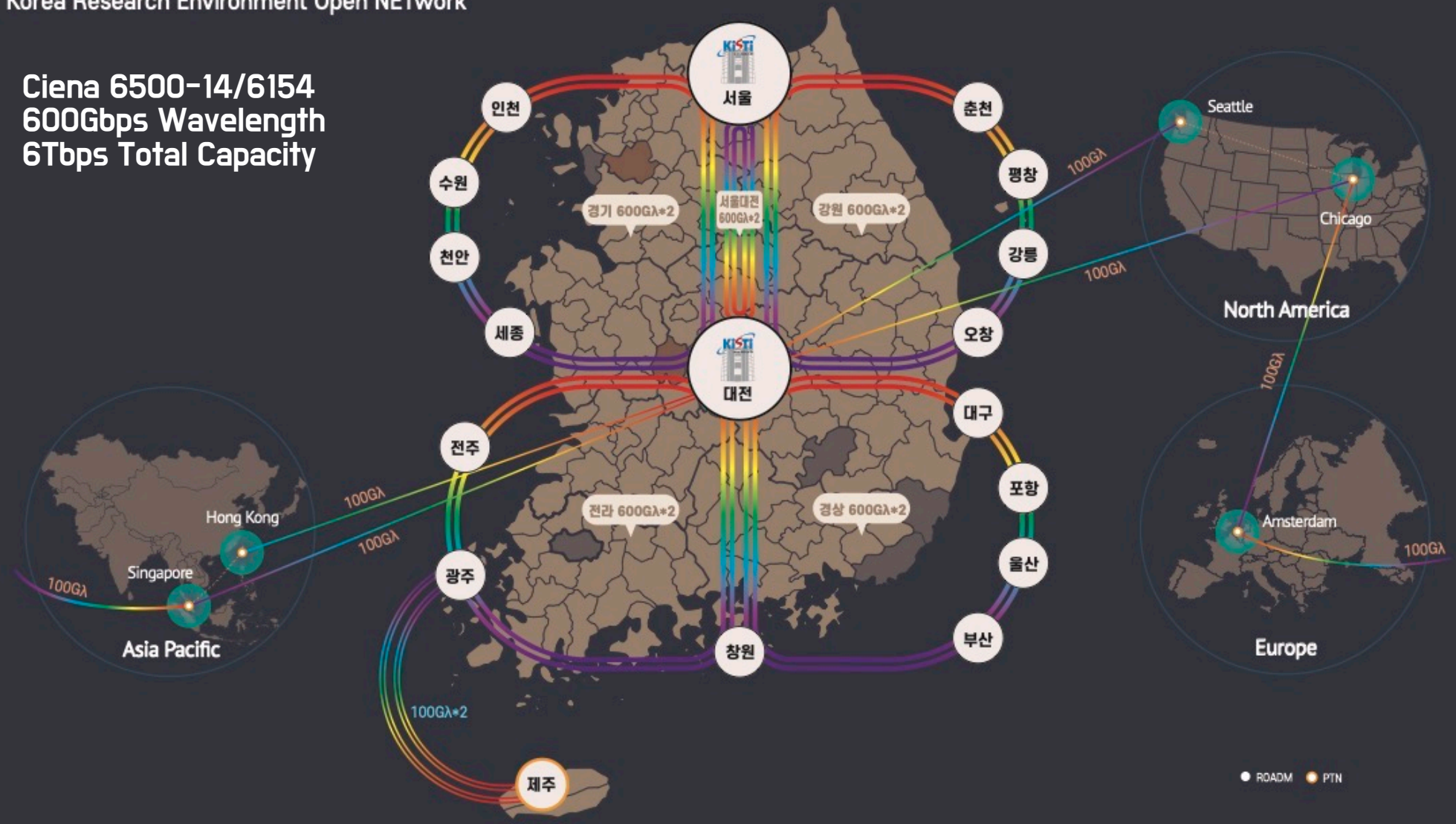
- KREONET (Korea Research Environment Open Network)
- Korea's National Science & Research Network, managed and operated by KISTI since 1988
- Advanced Research Network in "Utilization and Promotion of National Supercomputing" Act (implemented in 2011 in Korea)
- **First 600Gbps wavelength national-wide optical backbone in Asia**
- **100Gbps/400Gbps national-wide backbone with 18 Domestic Regional GigaPoPs and 6 International GigaPoPs**
- About 200 connected R&E organizations : National Research Institute and Lab, University, University Hospital, Research Institute of Company, library, Public Sector etc.
- 365*24 NOC (Network Operation Center) Service
- Directly linking domestic internet exchanges (KT, LG-U+, Sejoing Telecom) and international internet exchanges (GIX/Seoul, Cogent/Seattle, AMS-IX/Amsterdam, HK-IX)
- Directly connected to network of public clouds (Google, Amazon, Microsoft)
- **L1 Lightpath, L2 VPN, L3 R&E IP service, Science DMZ**
- **ID Federation, Korea Access Federation (KAFE), a member of eduGAIN**

NDeX (National Data eXchange)

KREONET Optical Backbone 2023

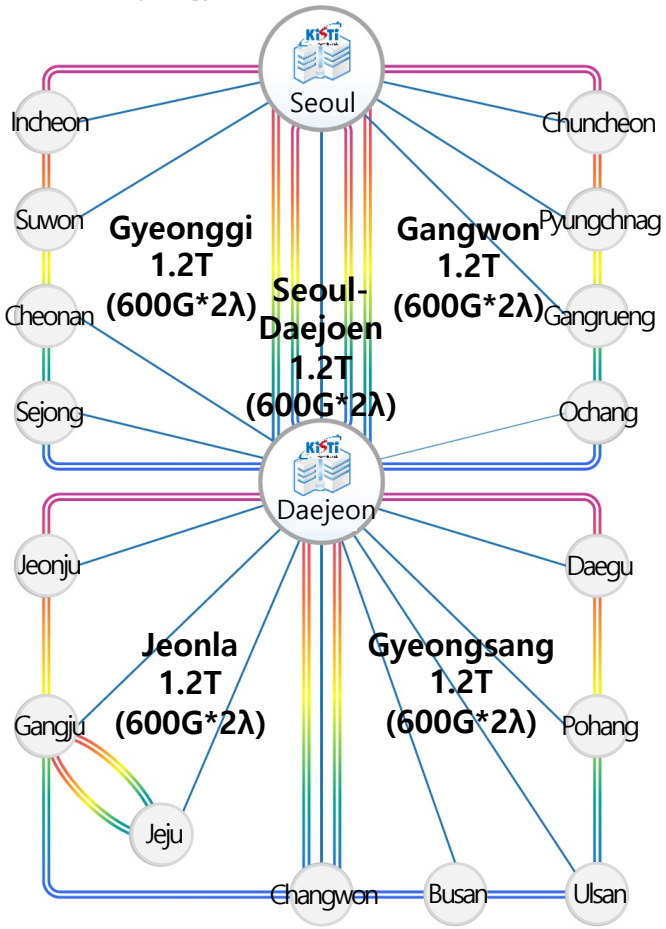
Korea Research Environment Open NETwork

Ciena 6500-14/6154
600Gbps Wavelength
6Tbps Total Capacity

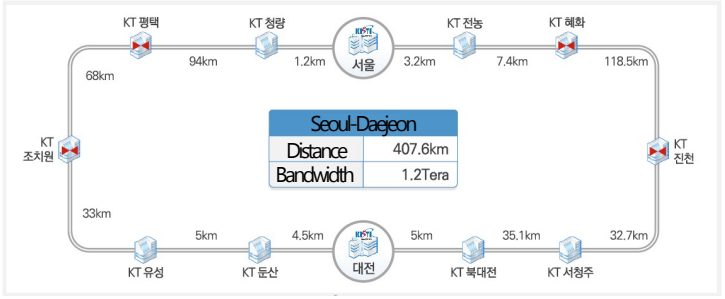


KREONET Optical Transport System

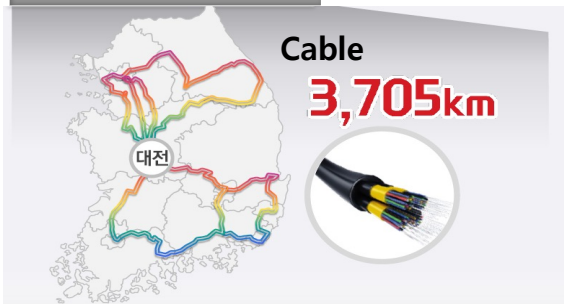
Topology



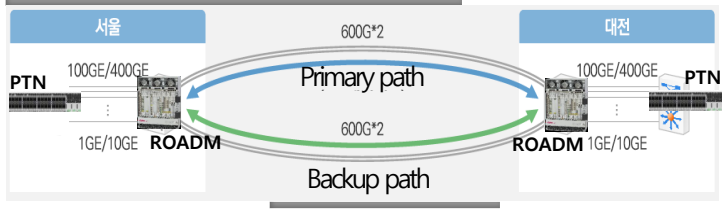
Physical Path (Seoul-Daejeon Ring)



Cable Path

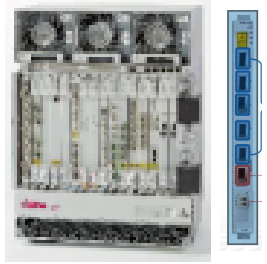


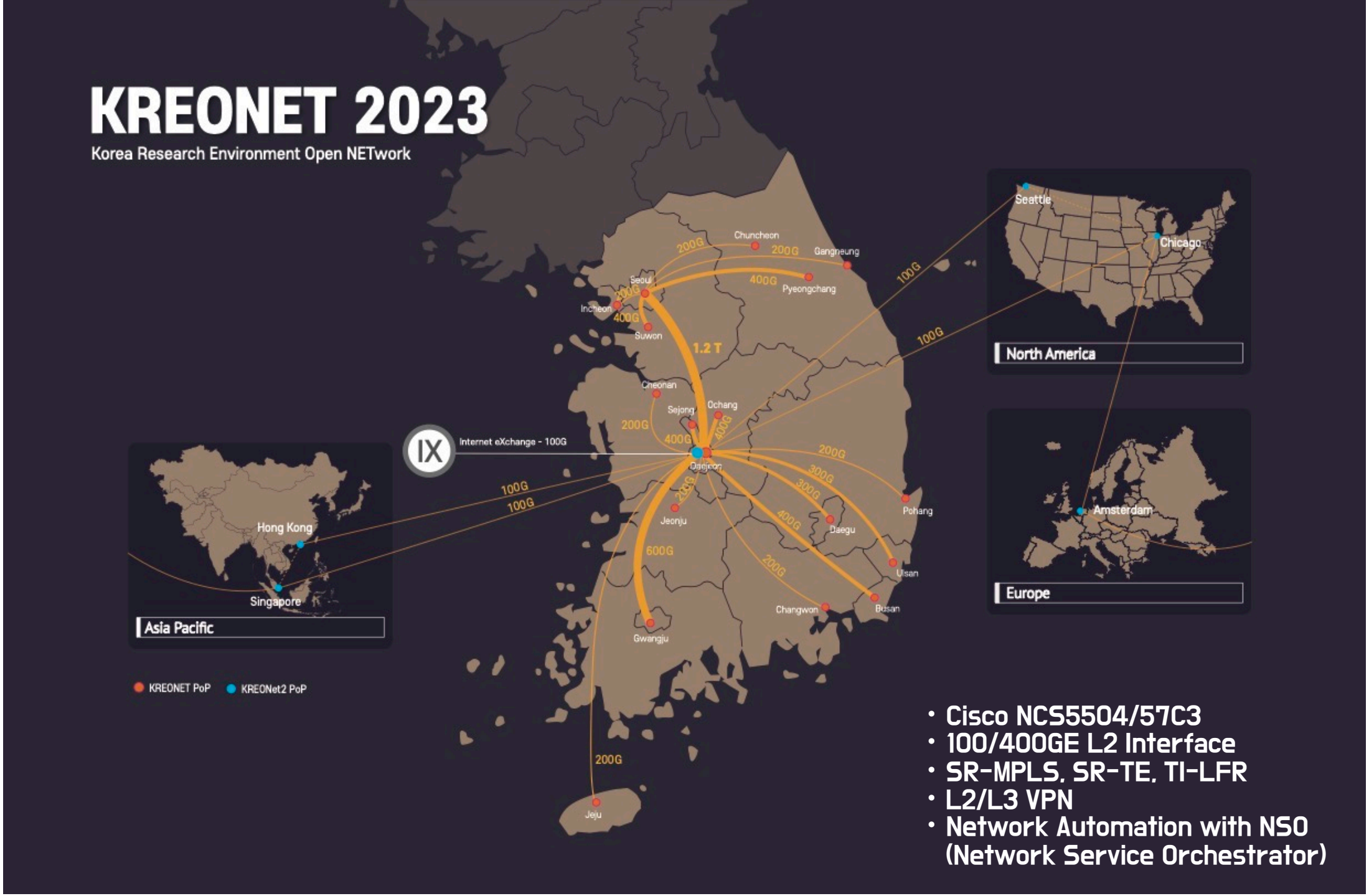
Logical Path (Seoul-Daejeon Ring)



Redundant Path(Daejeon)

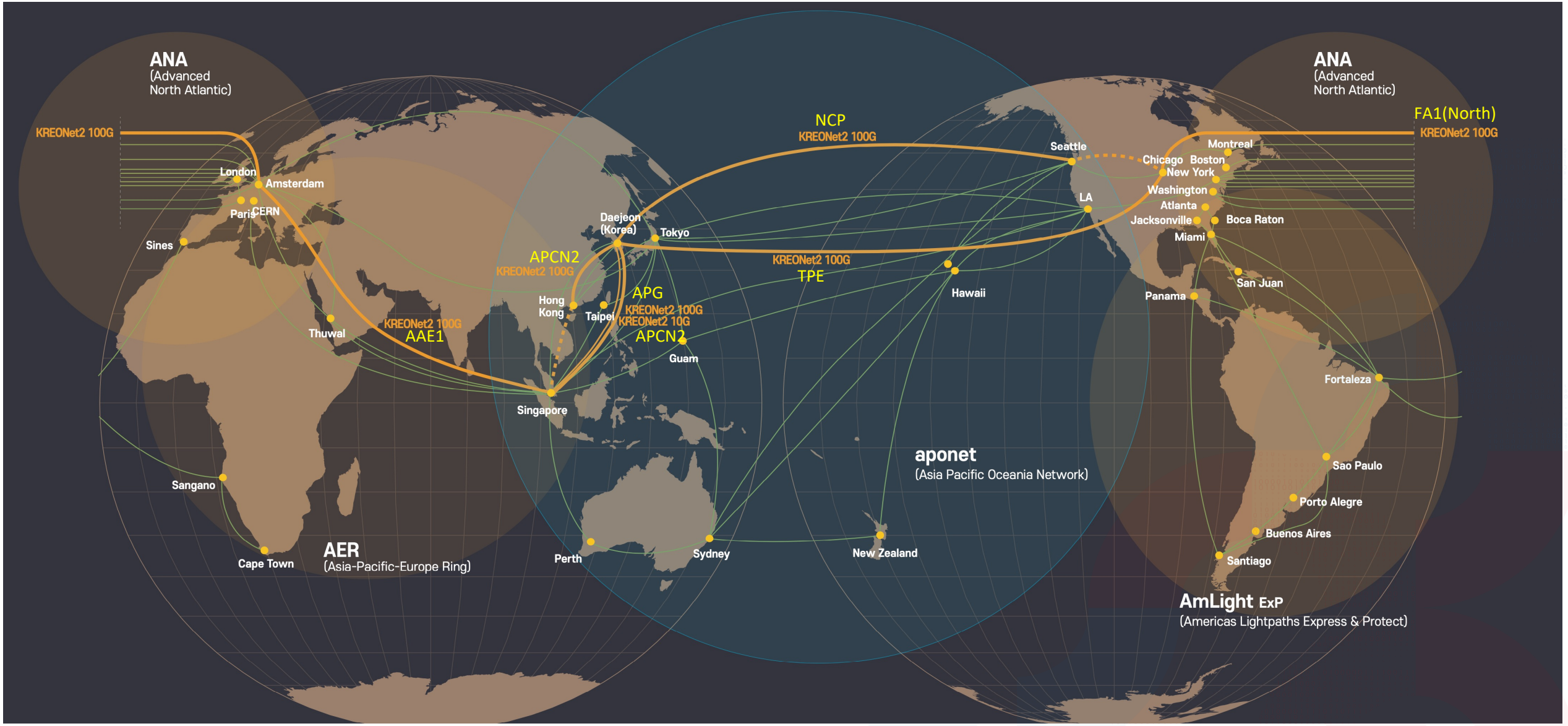
Devices

ROADM	Ciena AF6500-14	PTN	Ciena 5164
	• POTN/**ROADM**/CE • Wavelength : 42ch 800G support • WaveLogic 5e MOTR : - 95Gbaud - 112.5Ghz spacing - NNI(600G) - UNI(400G or 100G)		• MPLS-TP • Segment Routing • 200GbE(QSFP54) • 100GbE(QSFP28) • 1/10/25GbE(SFP) • (**CE**) E-LINE, E-LAN, E-TREE



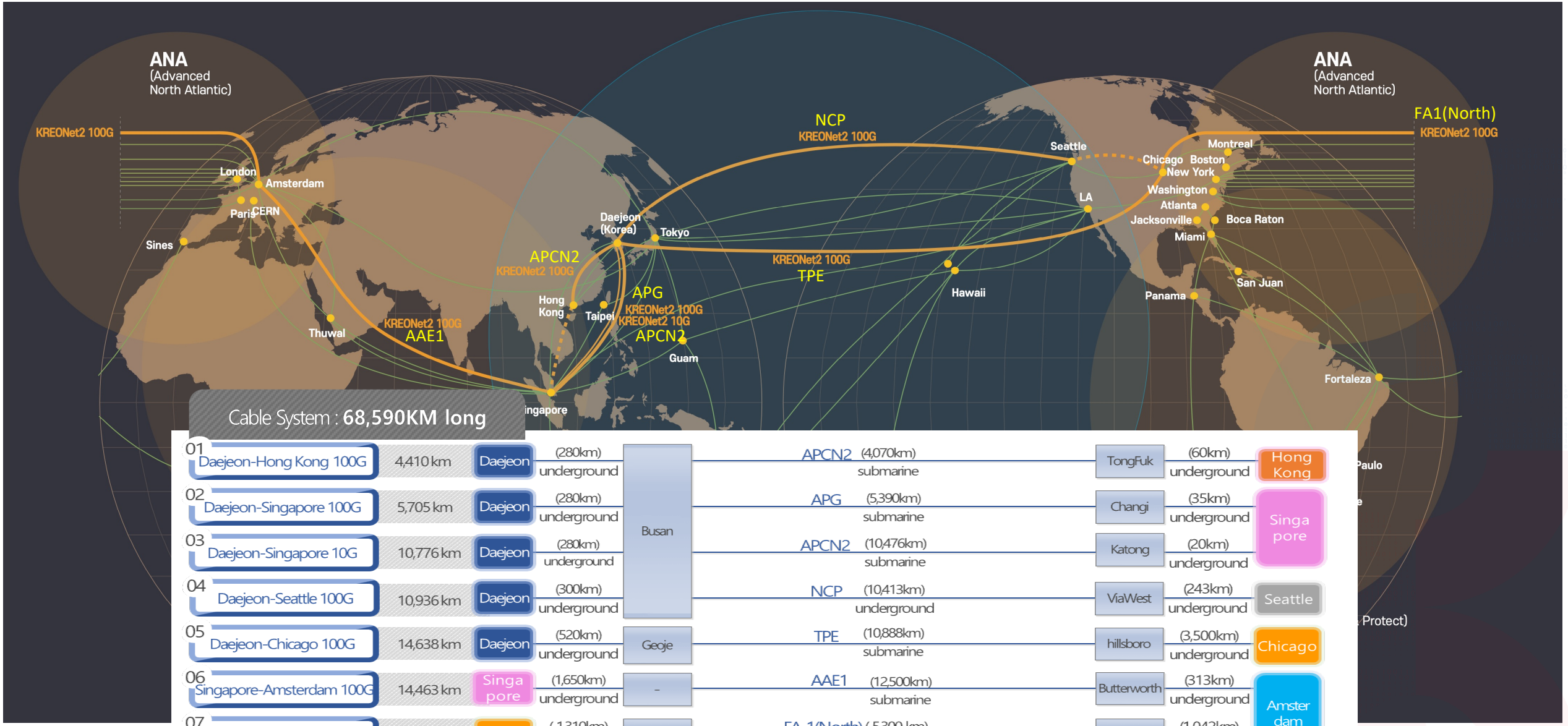
- Cisco NCS5504/57C3
- 100/400GE L2 Interface
- SR-MPLS, SR-TE, TI-LFR
- L2/L3 VPN
- Network Automation with NSO (Network Service Orchestrator)

KREONet2, International



Ciena 6500-14, Cisco NCS5504/57C3

KREONet2, International

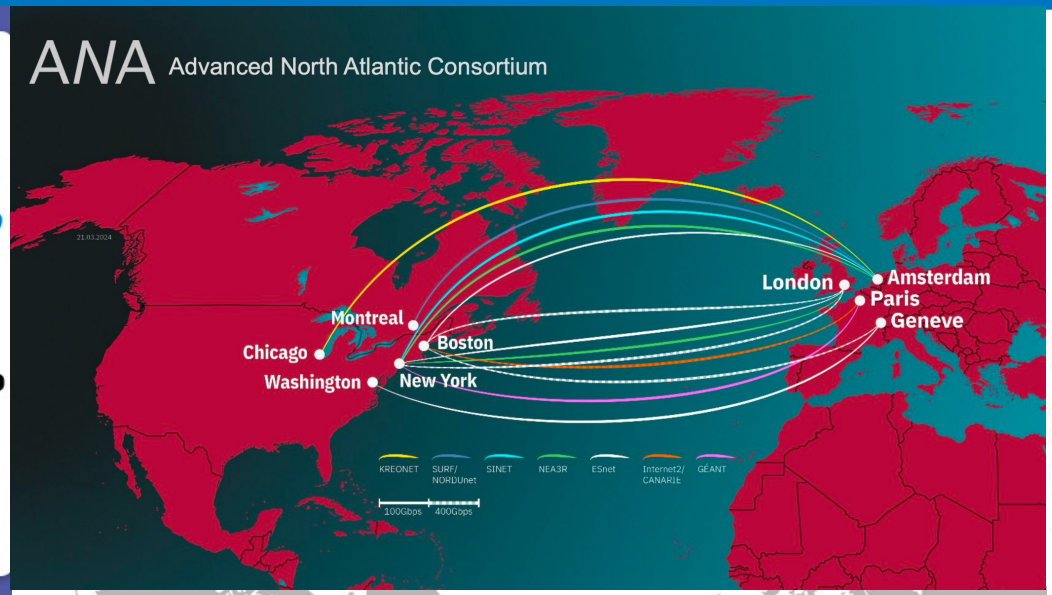


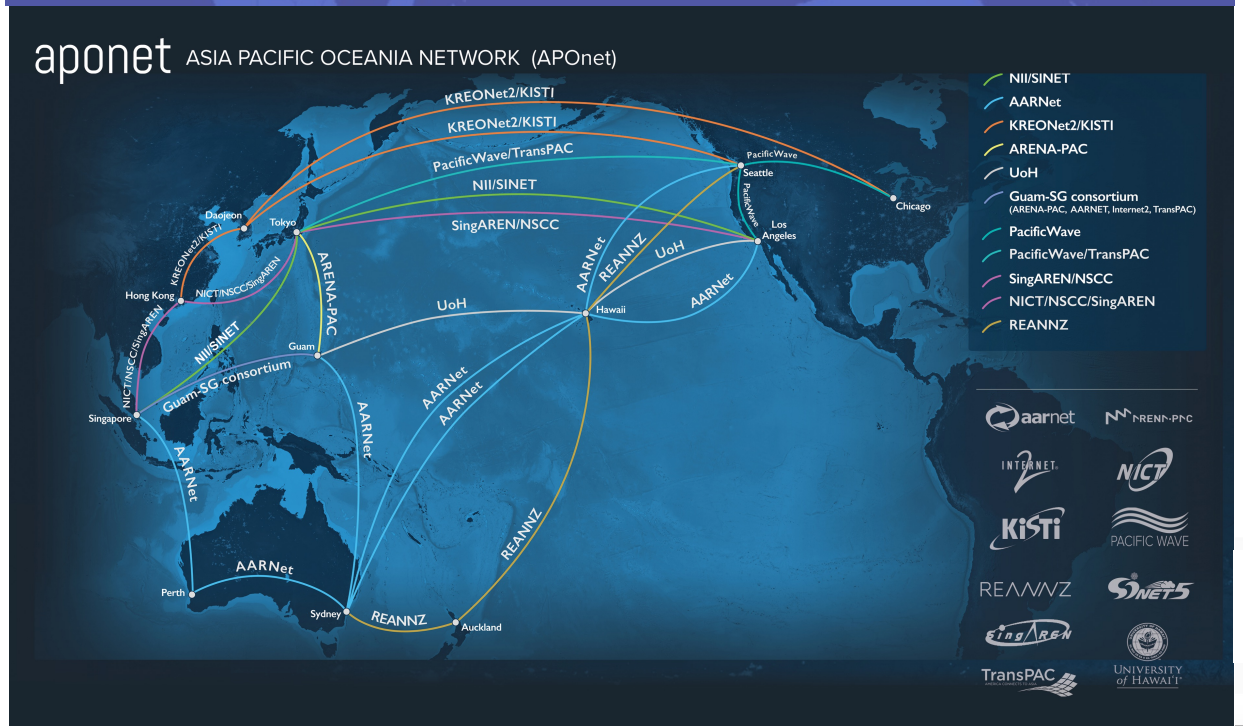
Cable System : **68,590KM long**

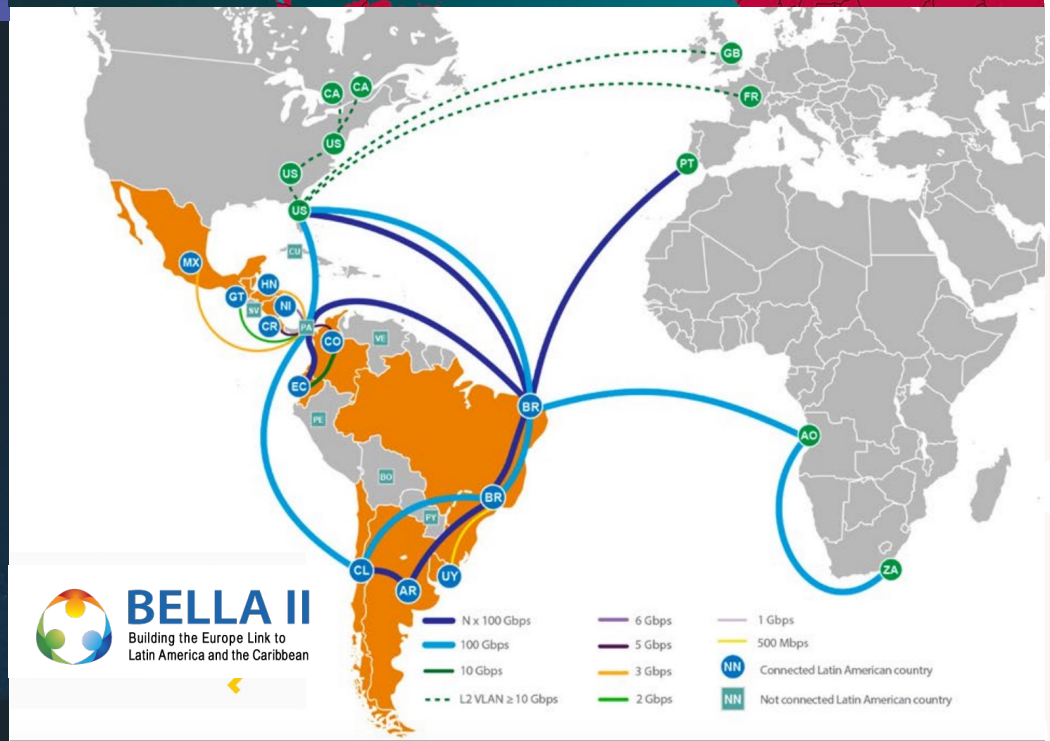
01	Daejeon-Hong Kong 100G	4,410 km	Daejeon	(280km) underground	Busan	APCN2	(4,070km) submarine	TongFuk	(60km) underground	Hong Kong
02	Daejeon-Singapore 100G	5,705 km	Daejeon	(280km) underground		APG	(5,390km) submarine	Changi	(35km) underground	Singa pore
03	Daejeon-Singapore 10G	10,776 km	Daejeon	(280km) underground		APCN2	(10,476km) submarine	Katong	(20km) underground	
04	Daejeon-Seattle 100G	10,936 km	Daejeon	(300km) underground		NCP	(10,413km) underground	ViaWest	(243km) underground	Seattle
05	Daejeon-Chicago 100G	14,638 km	Daejeon	(520km) underground	Geoje	TPE	(10,888km) submarine	hillsboro	(3,500km) underground	Chicago
06	Singapore-Amsterdam 100G	14,463 km	Singa pore	(1,650km) underground	-	AAE1	(12,500km) submarine	Butterworth	(313km) underground	Amster dam
07	Chicago-Amsterdam 100G	7,652 km	Chicago	(1,310km) underground	NorthPort	FA-1(North)	(5,300 km) submarine	Skewjack	(1,042km) underground	

Ciena 6500

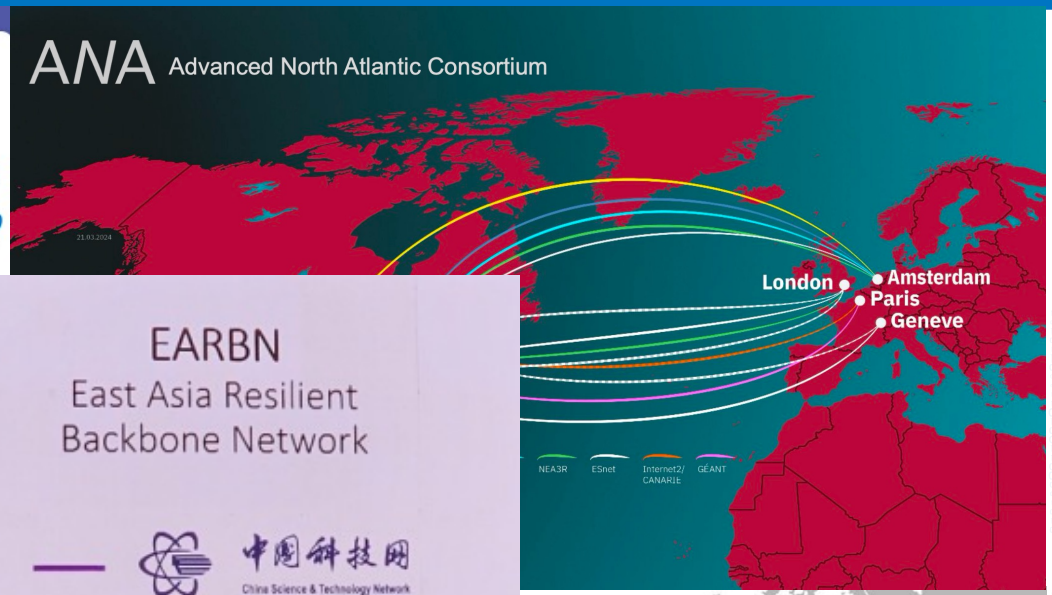
Global Research and Education Network (GREN), GNA-G Compliant

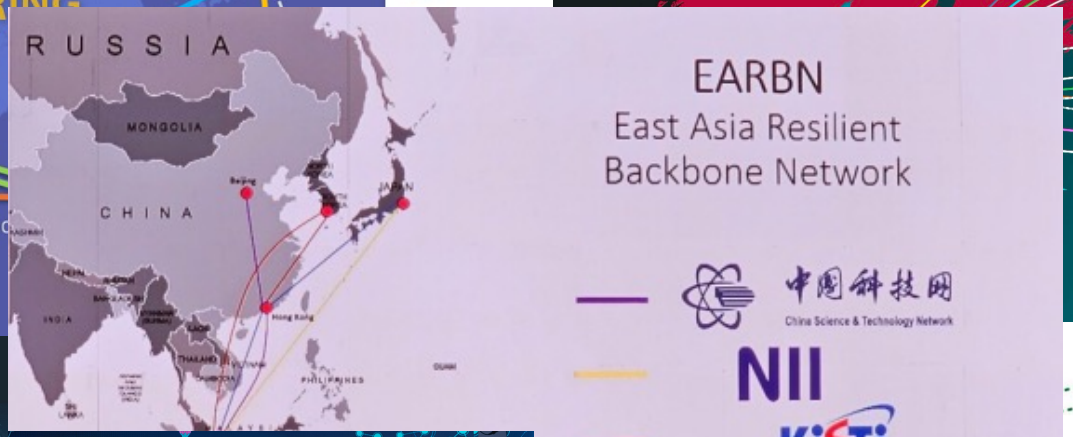


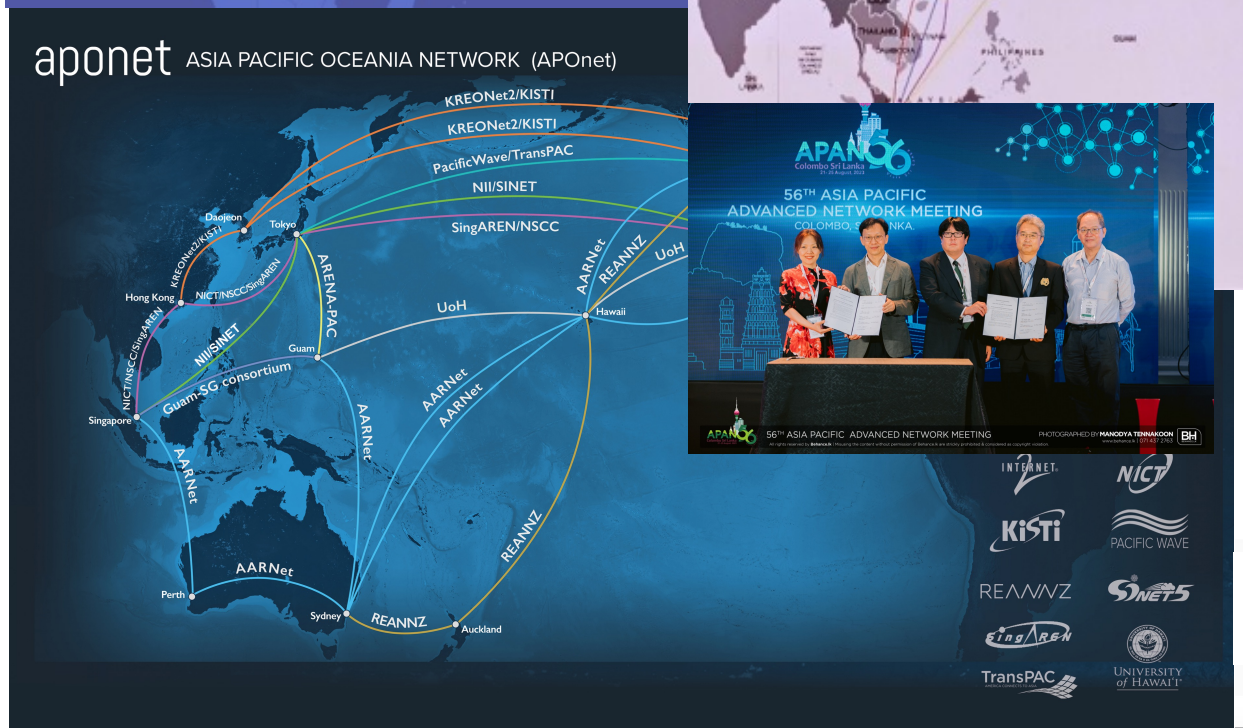


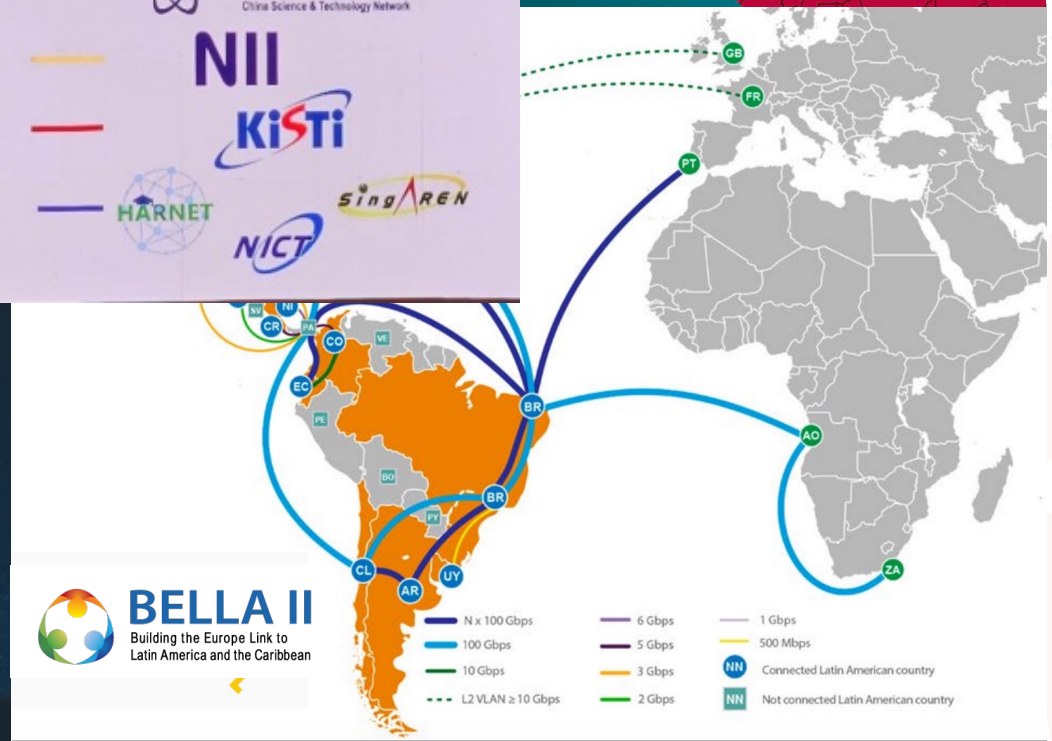


Global Research and Education Network (GREN), GNA-G Compliant

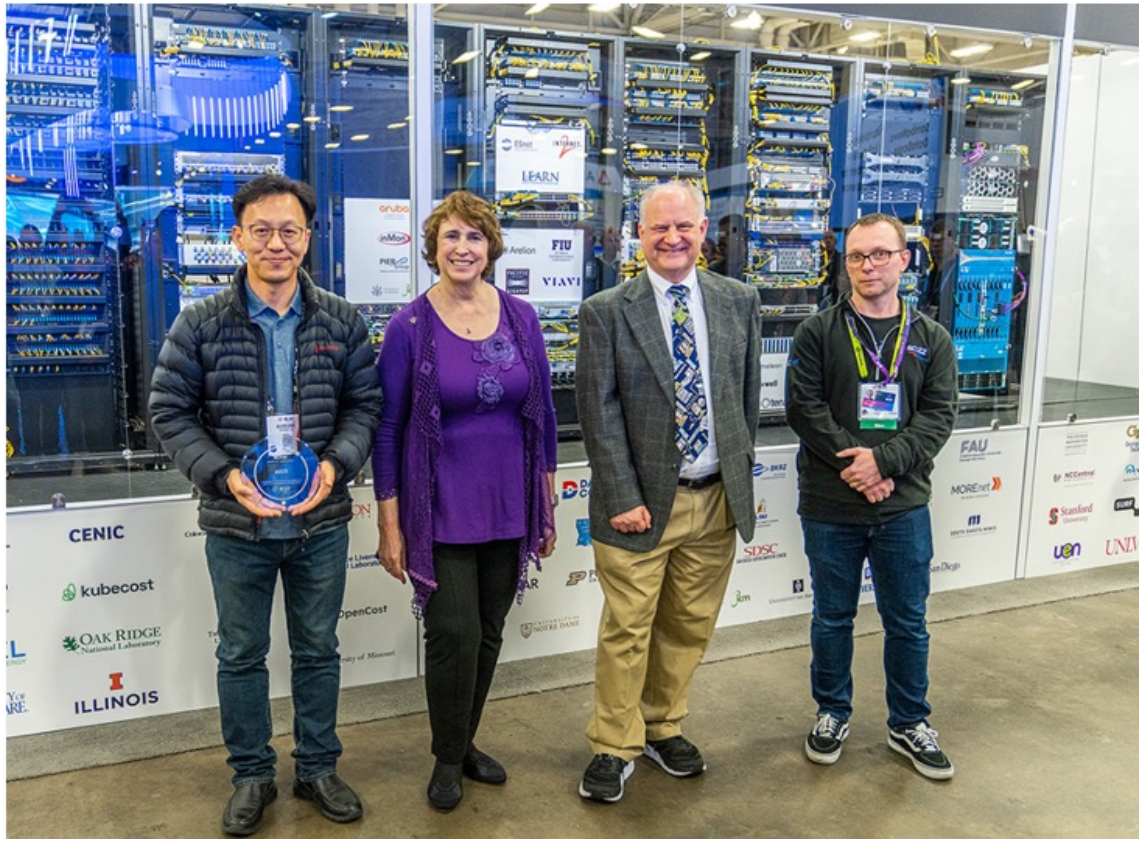








SCinet Spirit of Innovation Award Recognizes 17 Contributors' Role in Supporting International Science Activities for SC22



"The winners of the 2022 SCinet Spirit of Innovation Award have **embraced the spirit of collaboration and cooperation** that showcases the best there is to offer in demonstrating, implementing, and operating leading-edge solutions to challenging problems," said Matt Zekauskas, SCinet Chair. "This collaboration is truly special to SCinet, and we are all encouraged by and appreciative of their efforts to showcase partnership and innovation."

...

AARNet, APONET, ARENA-PAC, CENIC, Ciena, Cisco, HARNET, Internet2, KISTI, NICT, NII, Pacific Northwest Gigapop, REANNZ, SingAREN, TransPAC, University of Hawaii, and Verizon were recognized at a private ceremony on Monday, November 14.

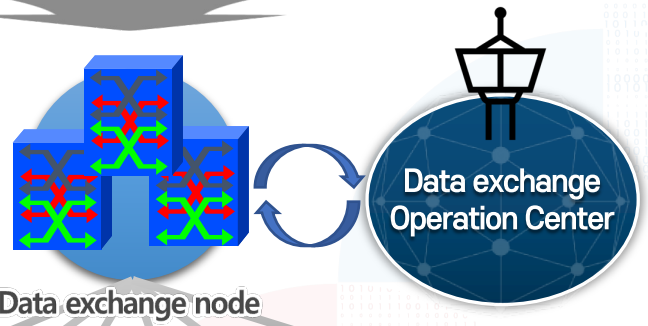
National Data eXchange (NDeX) Initiative, Korea

The **first NREN Open eXchange in Korea**, co-located with cloud datacenter (KT/KT Cloud) nearby the largest submarine cable landing station (CLS) in Busan city

4 Key Technologies of Data exchange

1. High Performance (non-blocking) Optical/Packet Switching Fabric	2. Software Data eXchange (SDX)
3. Trust-based access and control mechanism for Data exchange	4. High-precision Operation and Management of Data exchange

NDeX
National Data Exchange in Korea



Data exchange node

Public/Private Cloud Network

National Supercomputing Network

Global Science Network (Hub)

Commercial Internet Exchange

Data Dam Network

KREONET

Korean VLBI Network (KVN)

National Data eXchange (NDeX) Initiative, Korea

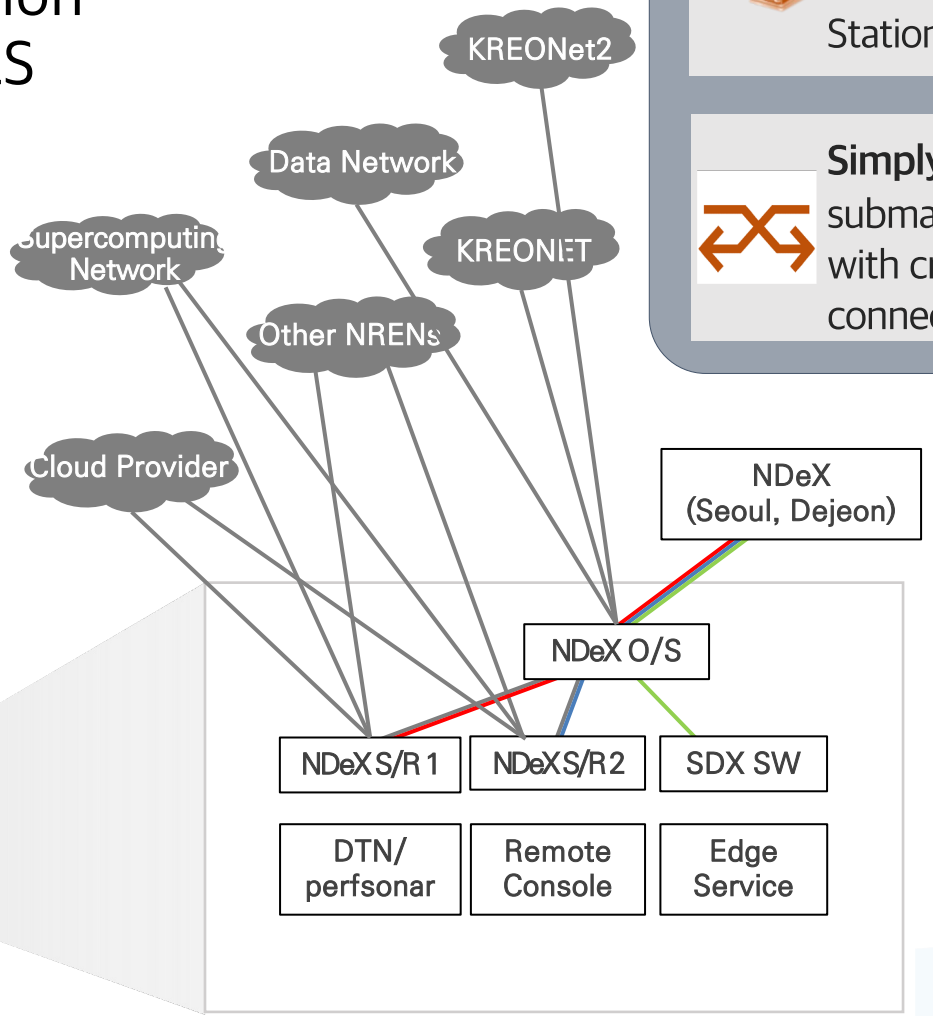
- Opened in July, 2023
- Free backhaul connection between NDeX and CLS

The first Open Exchange located in Busan Cable Landing Station ever

Enough capacity of Submarine cables from East and West

Simply connect on submarine cables with cross-connections

Operated by Experts Group of Submarine Cable NOC (KT/KT Cloud) and KISTI



LHCOPN, LHCONE and HEP Net work of KREONET

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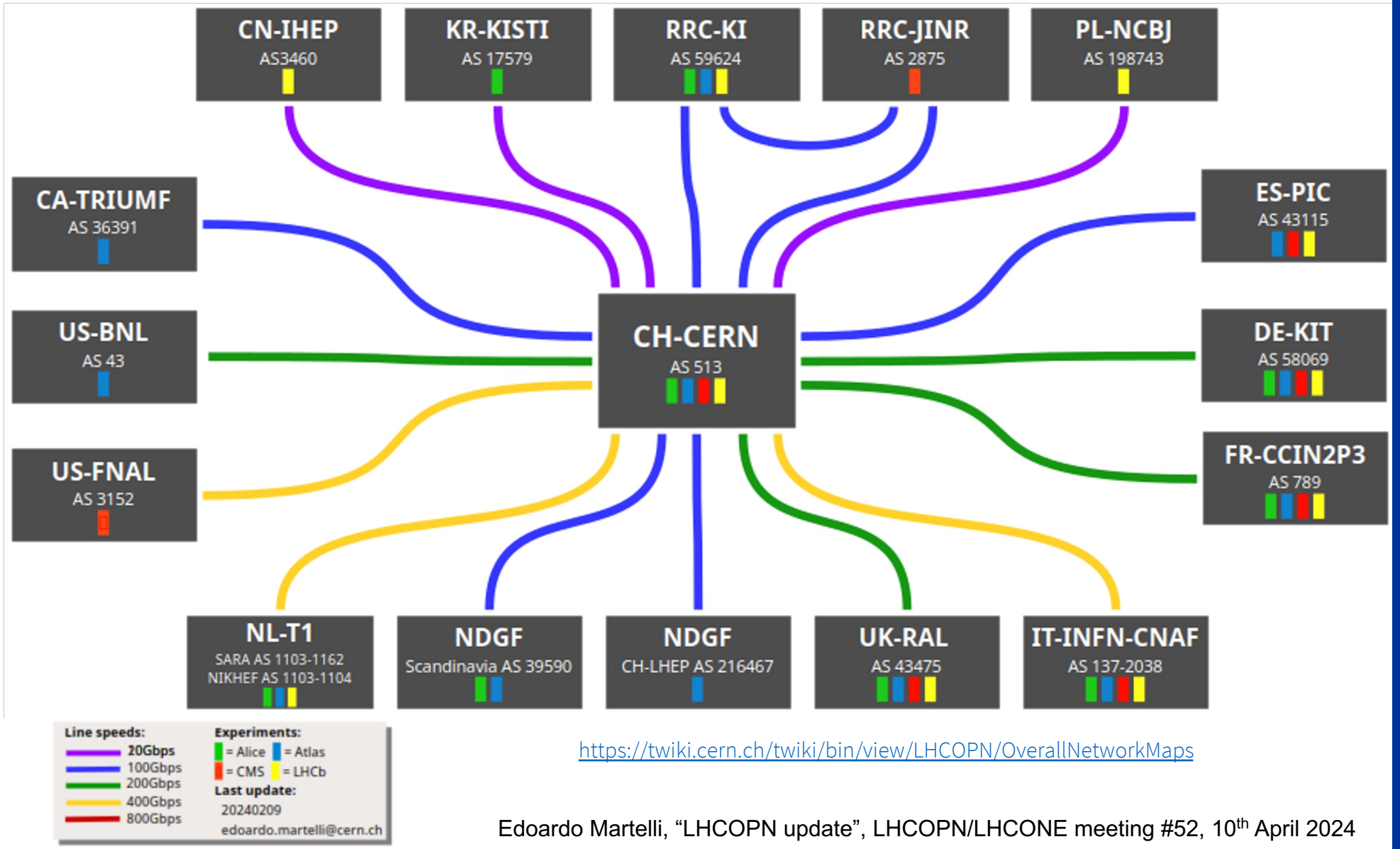
Changing the world with Data KiSTi

KREONET

LHCOPN

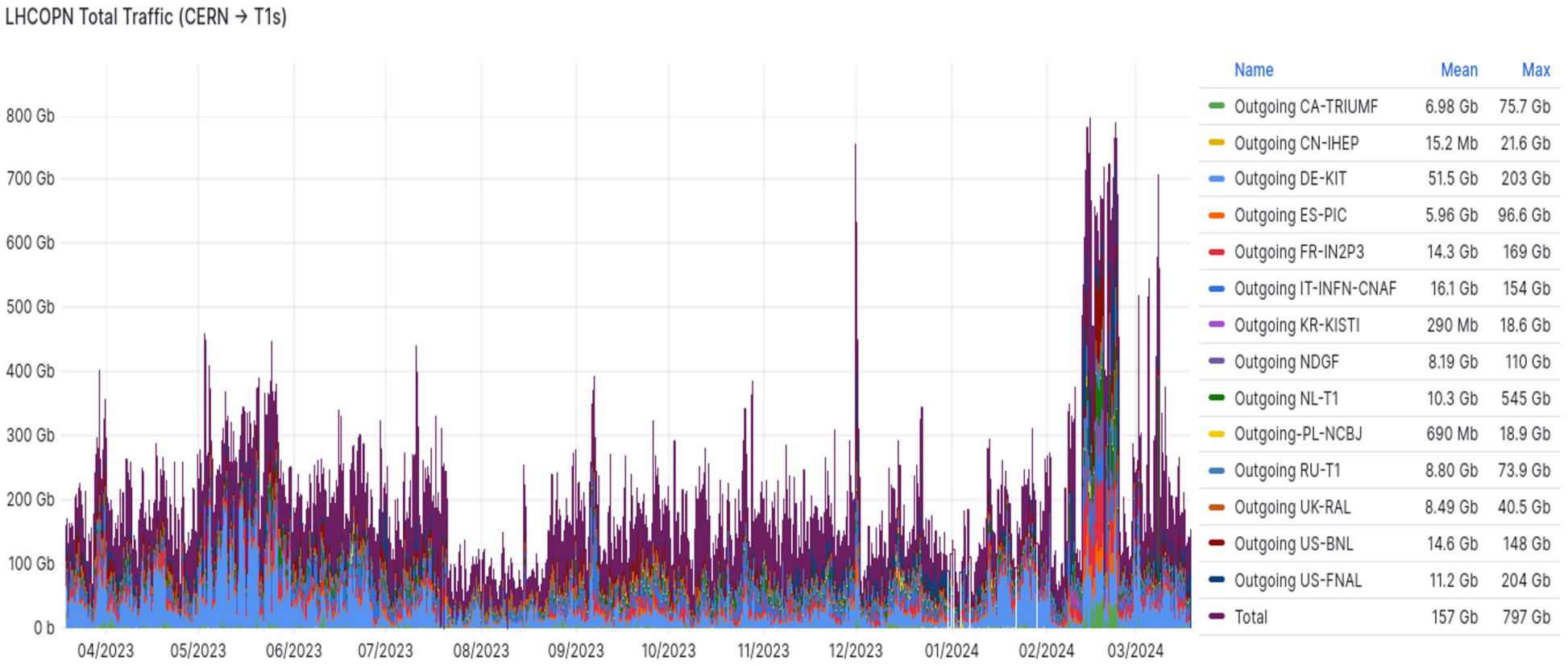


https://twiki.cern.ch/twiki/bin/view/LHCOPN/OverallNetworkMaps

Numbers

- 17 sites for 15 Tier1s + 1 Tier0
- From 20Gbps to 400Gbps
- 14 countries in 3 continents
- 2.66 Tbps to the Tier0
- CN-IHEP and NDFG-LHEP last connected
- TW-ASGC has left [50]

LHCOPN Traffic – last 12 months



Name	Mean	Max
Outgoing CA-TRIUMF	6.98 Gb	75.7 Gb
Outgoing CN-IHEP	15.2 Mb	21.6 Gb
Outgoing DE-KIT	51.5 Gb	203 Gb
Outgoing ES-PIC	5.96 Gb	96.6 Gb
Outgoing FR-IN2P3	14.3 Gb	169 Gb
Outgoing IT-INFN-CNAF	16.1 Gb	154 Gb
Outgoing KR-KISTI	290 Mb	18.6 Gb
Outgoing NDGF	8.19 Gb	110 Gb
Outgoing NL-T1	10.3 Gb	545 Gb
Outgoing-PL-NCBJ	690 Mb	18.9 Gb
Outgoing RU-T1	8.80 Gb	73.9 Gb
Outgoing UK-RAL	8.49 Gb	40.5 Gb
Outgoing US-BNL	14.6 Gb	148 Gb
Outgoing US-FNAL	11.2 Gb	204 Gb
Total	157 Gb	797 Gb

Numbers:

Moved ~619 PB in the last 12 months

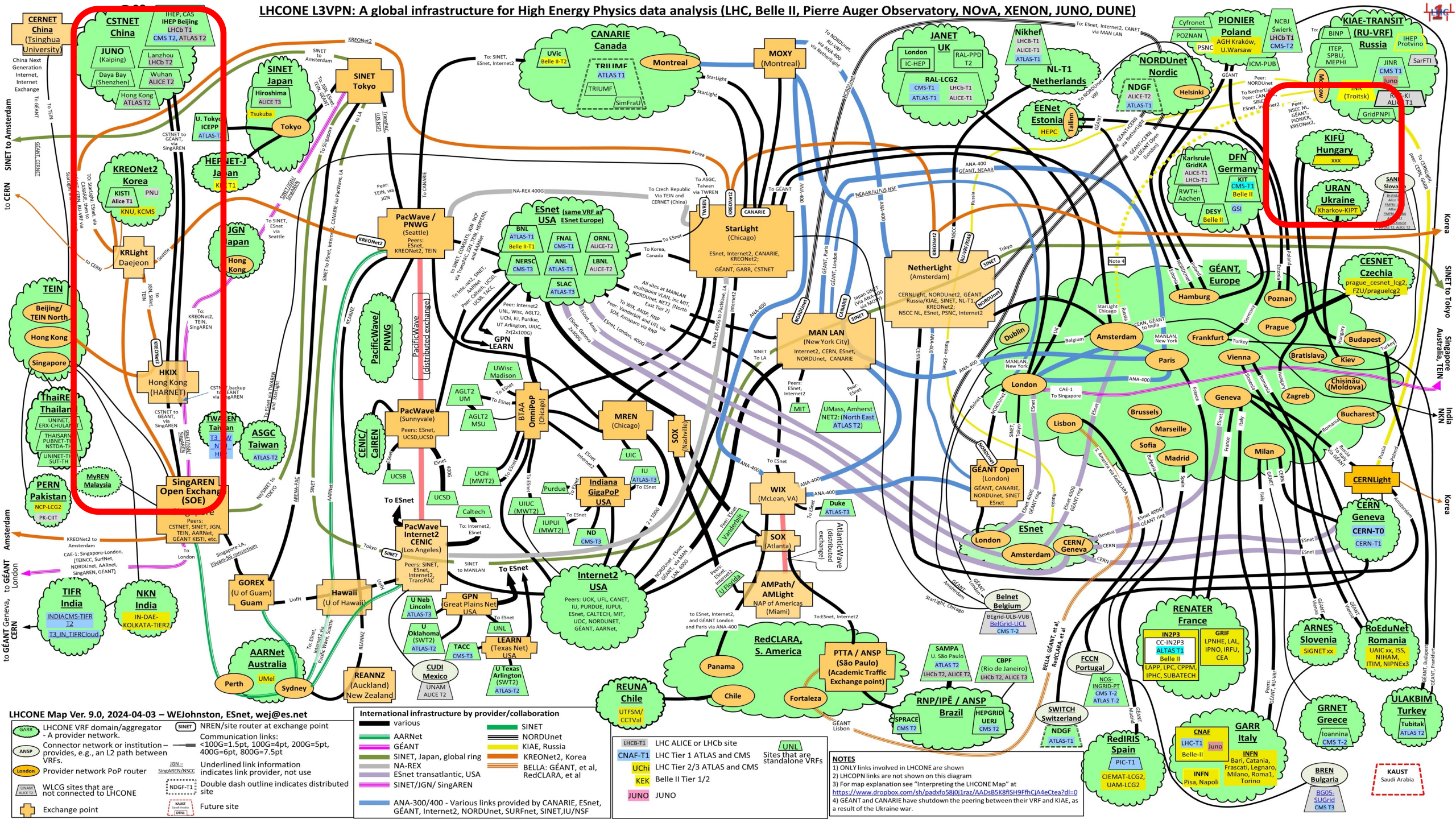
+27% compared to previous year (488PB)

Peak at ~800Gbps (during DC24)

50

Ref: https://monit-grafana-open.cern.ch/d/HreVOyc7z/all-lhcopn-traffic?orgId=16

LHCONE L3VPN: A global infrastructure for High Energy Physics data analysis (LHC, Belle II, Pierre Auger Observatory, NOvA, XENON, JUNO, DUNE)



LHCONE Map Ver. 9.0, 2024-04-03 – WEJohnston, ESnet, wej@es.net

- GARR — LHCONE VRF domain/aggregator - A provider network.
- ANSP — Connector network or institution – provides, e.g., an L2 path between VRFs.
- London — Provider network PoP router
- UNAM ALICE T2 — WLCG sites that are not connected to LHCONE
- Exchange point
- SINET — NREN/site router at exchange point
- Communication links: <100G=1.5pt, 100G=4pt, 200G=5pt, 400G=6pt, 800G=7.5pt
- JGN – SingAREN/NSCC — Underlined link information indicates link provider, not use
- NDGF-T1 — Double dash outline indicates distributed site
- KAUST Saudi Arabia DTN1 — Future site

International infrastructure by provider/collaboration

- various
- AARNet
- GÉANT
- SINET, Japan, global ring
- NA-REX
- ESnet transatlantic, USA
- SINET/JGN/ SingAREN
- SINET
- NORDUnet
- KIAE, Russia
- KREONet2, Korea
- BELLA: GÉANT, et al, RedCLARA, et al
- ANA-300/400 - Various links provided by CANARIE, ESnet, GÉANT, Internet2, NORDUnet, SURFnet, SINET,IU/NSF

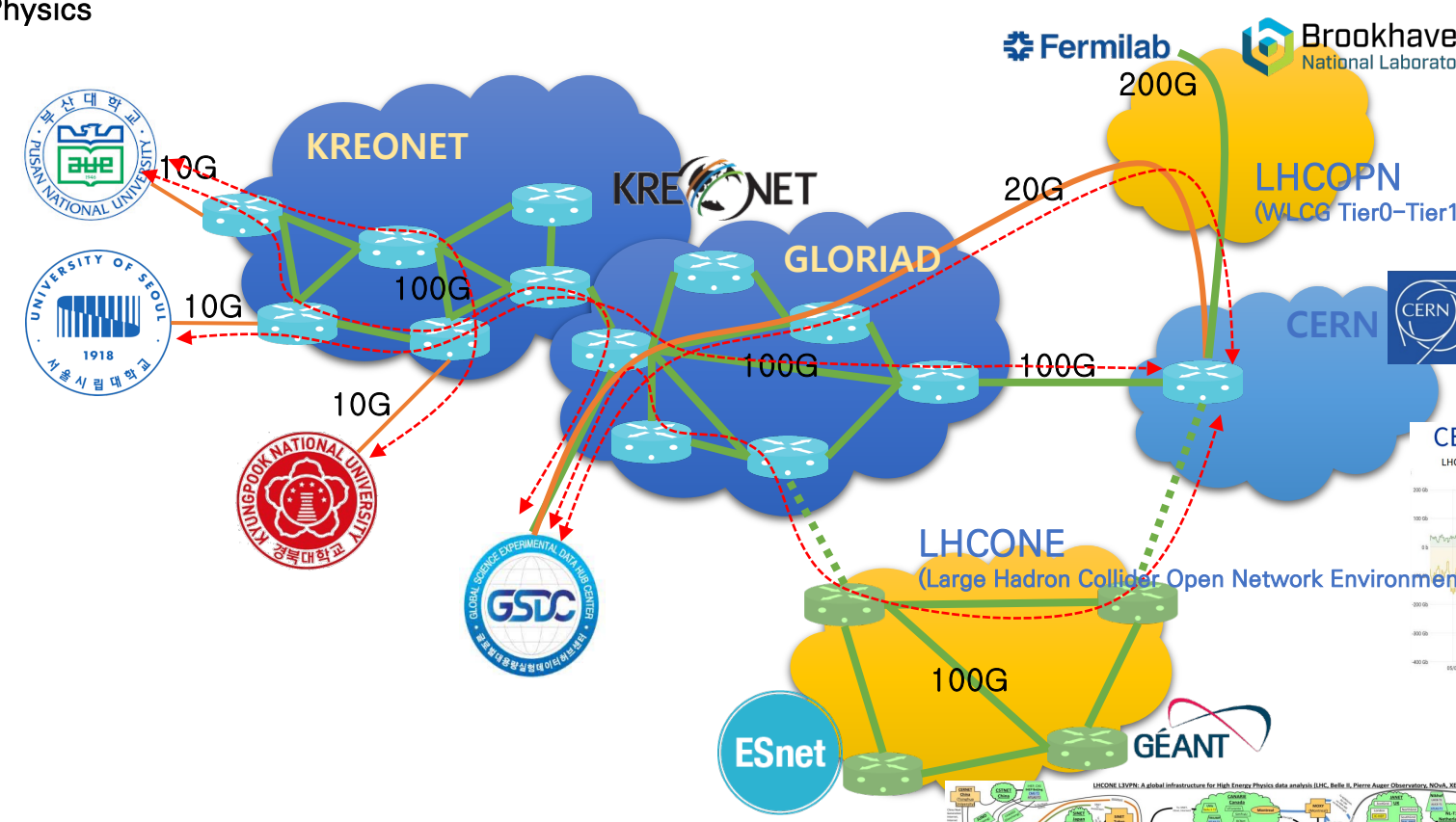
- LHCB-T1 — LHC ALICE or LHCb site
- CNAF-T1 — LHC Tier 1 ATLAS and CMS
- UChi — LHC Tier 2/3 ATLAS and CMS
- KEK — Belle II Tier 1/2
- JUNO — JUNO
- UNL — Sites that are standalone VRFs

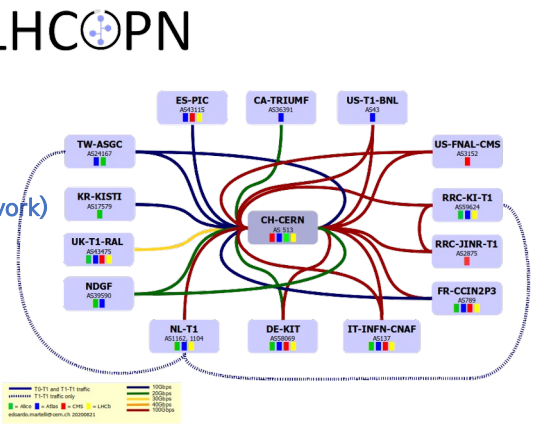
NOTES

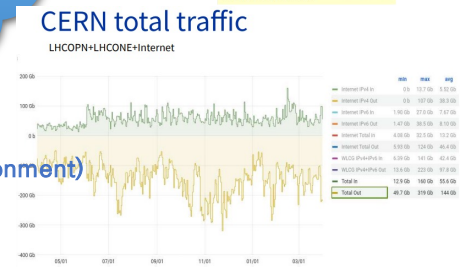
1) ONLY links involved in LHCONE are shown
2) LHCOPN links are not shown on this diagram
3) For map explanation see "Interpreting the LHCONE Map" at https://www.dropbox.com/sh/padxfo58j0j1raz/AADsB5K8fISH9FfhCjA4eCtea?dl=0
4) GÉANT and CANARIE have shutdown the peering between their VRF and KIAE, as a result of the Ukraine war.

HEP networks over KREONET/KREONet2

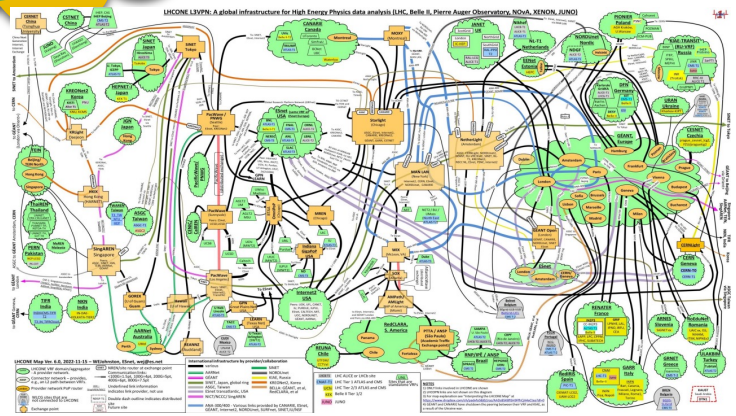
HEP: High Energy Physics



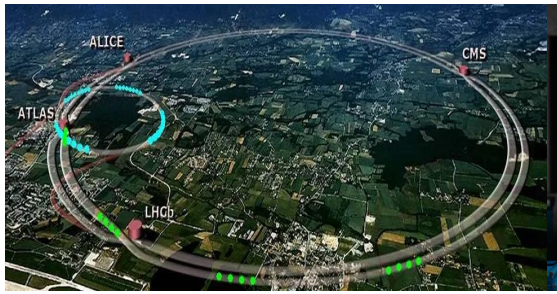




평균 100Gbps 이상



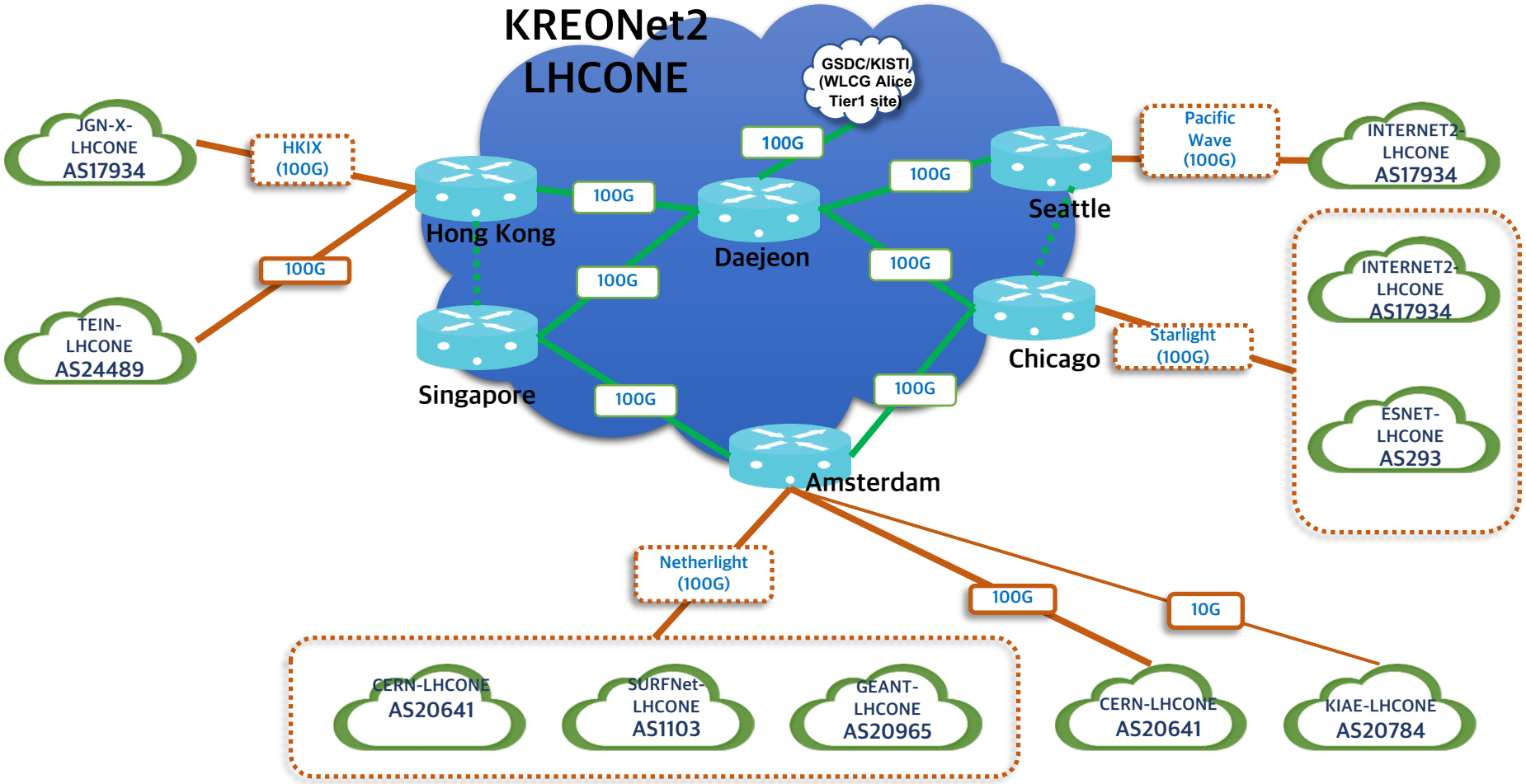
LHCONE MAP



CERN Large Hadron Collider

High-Luminosity LHC

KREONet2 LHCONE Expansion



KREONET Development and Application

S&T Infra,
Changing the world with Data KiSTi

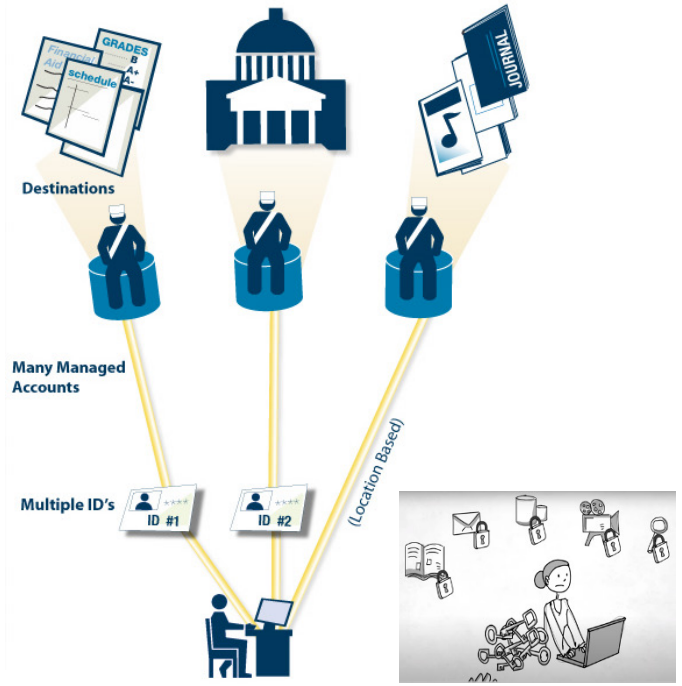
KREONET

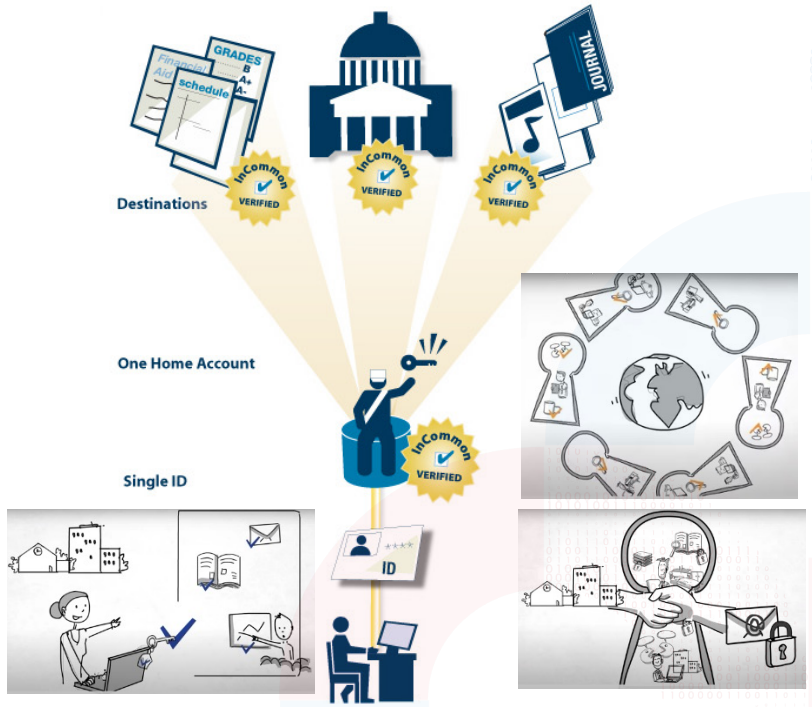
ID Federation: Korea Access Federation (KAFE)

Federated access to create a more trustworthy R&E environment for seamless collaboration

KAFE
Korean Access Federation, https://www.kafe.or.kr

Korea ID federation to manage trusted ID networking infrastructure of academic, research and industry in Korea





Legacy Access

Non-standard individual ID login for individual external services

Access based-on ID Federation

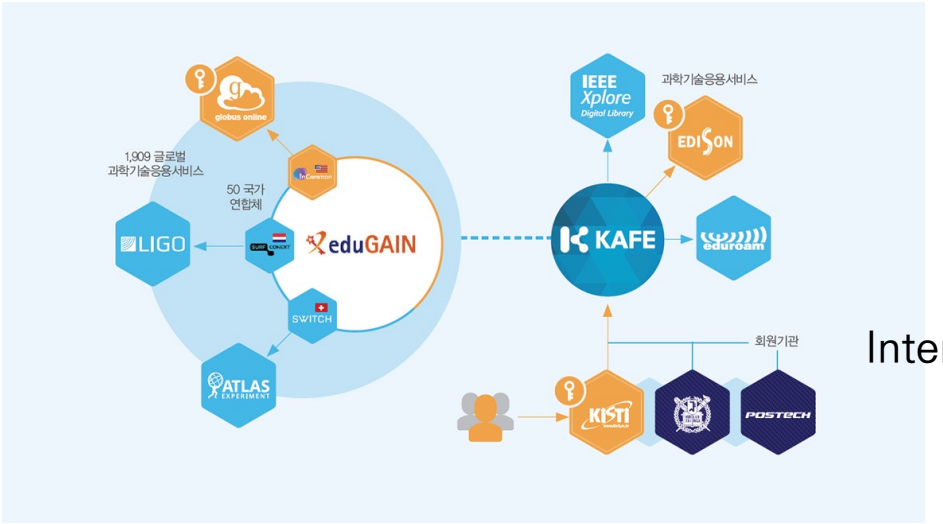
Standard-based integrated login, single sign-on

ID Federation: Korea Access Federation (KAFE)

78

Domestic members
(SNU, KAIST, etc)

KAFE Members

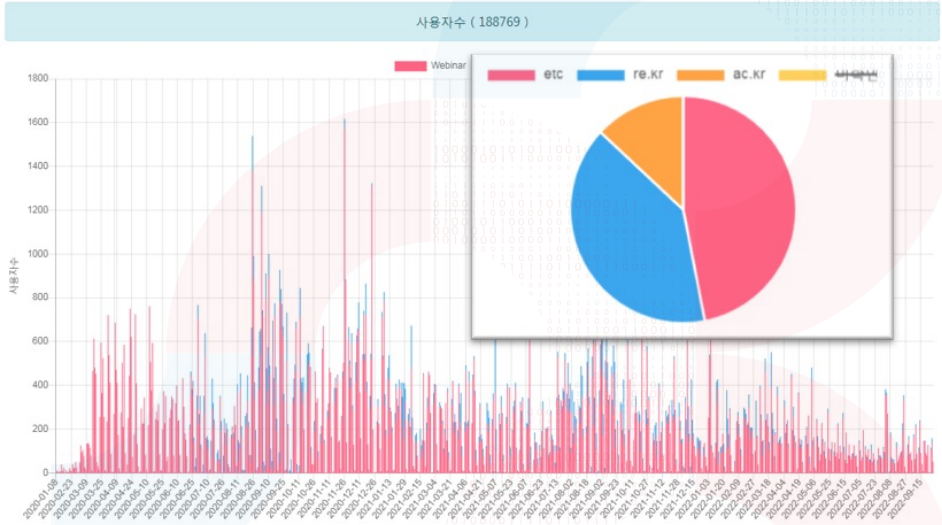


2,510

Inter-federated members
(CERN, CILogon, etc)

KAFE Federated Services

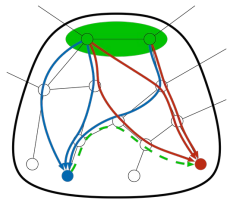
- KREONET Webinar, Globus, Portal
- KISTI SuperCom Cloud Service (KiCloud KAIROS)
- KISTI AI platform (AIDA), DataOn, ScienceOn
- IEEExplore, etc (E-journal)
- CERN, LIGO, OpenAIRE, ...

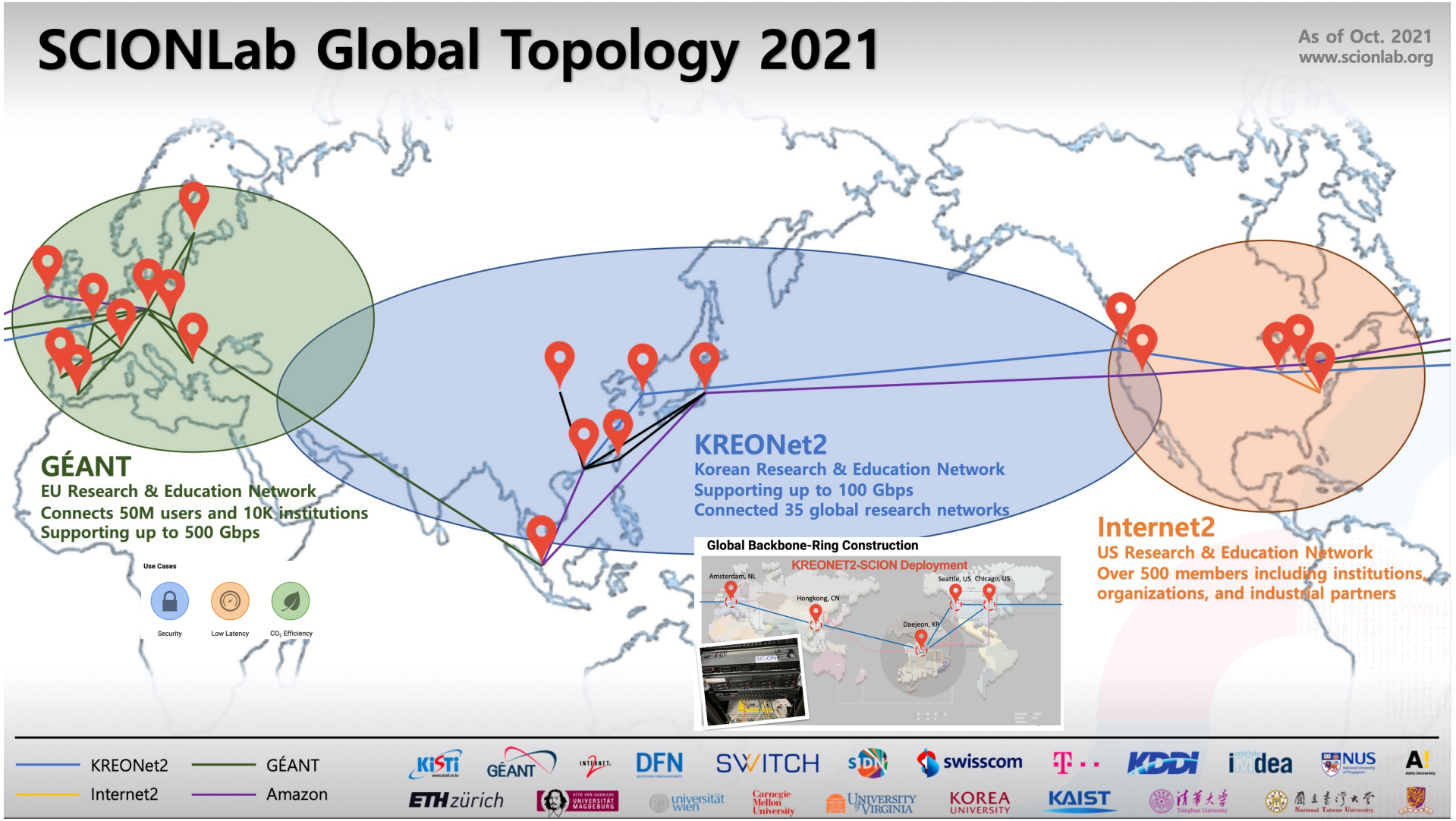


# of KREONET Webinar users

SCION (SCALABILITY, CONTROL, AND ISOLATION ON NEXT-GENERATION NETWORKS.)

Secure, path-aware, multipath networking

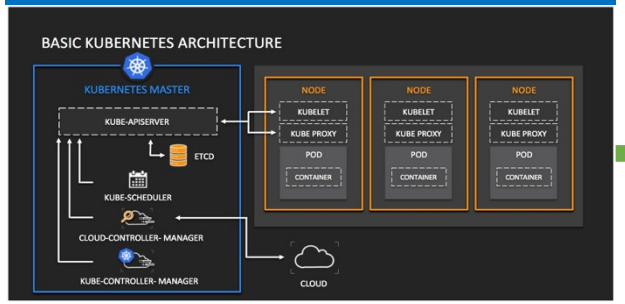




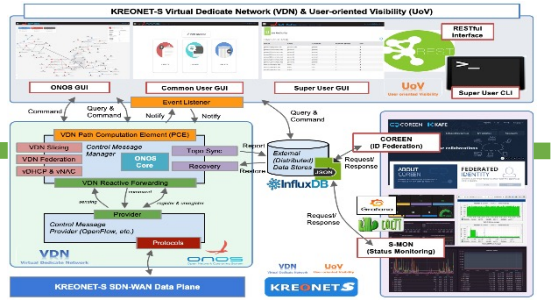
KREONET/KISTI-SCIONLAB/ETH Zurich : Secure Backbone AS (BGP hijack resilience), Low Latency Networking, CO_2-Oriented Path Selection

KREONET N-S-C Orchestration System (1)

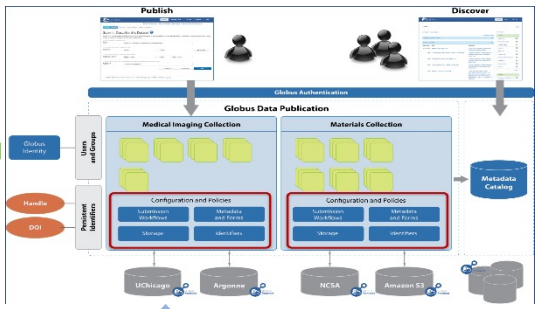
Kubernetes:
Storage & Computing Resources



Virtual Dedicated Network:
Networking Resources



Globus Online:
Research Data Management



Distributed User Sites
Edge Networks

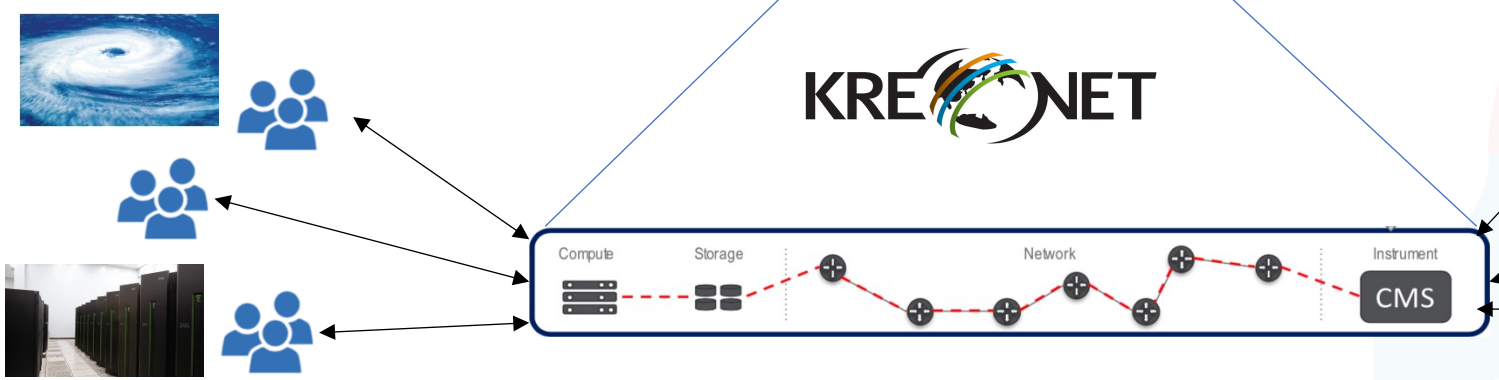
Wide-area SDN Infrastructure

Big Data Transfer,
Sharing, Publication,
and Discovery
via Software-as-a-Service

E2E High Performance Virtual Network Embedding

Physical & Virtual Service
Resource Provisioning on demand

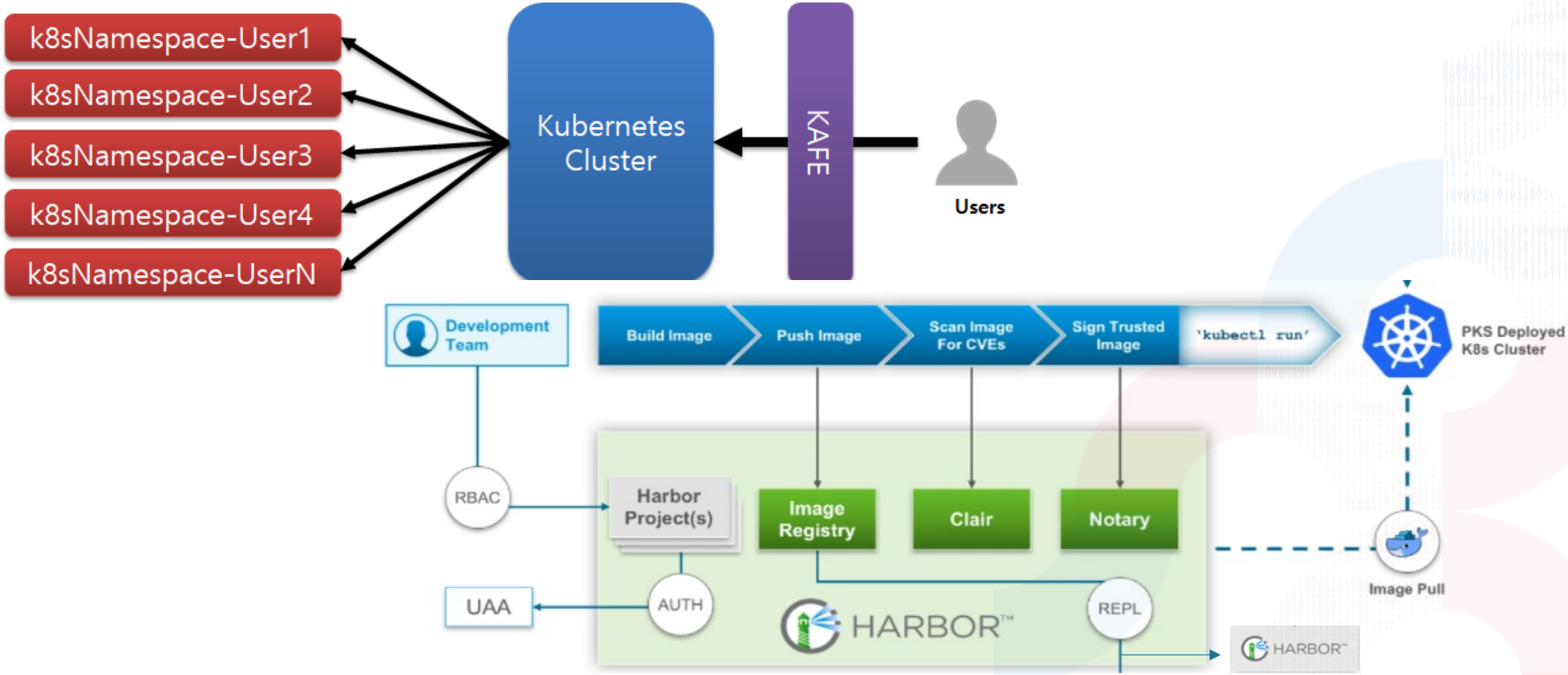
KREONET N-S-C Orchestrator



KREONET N-S-C Orchestration System (2)

1) k8s oriented Storage & Computing Resource Management Module

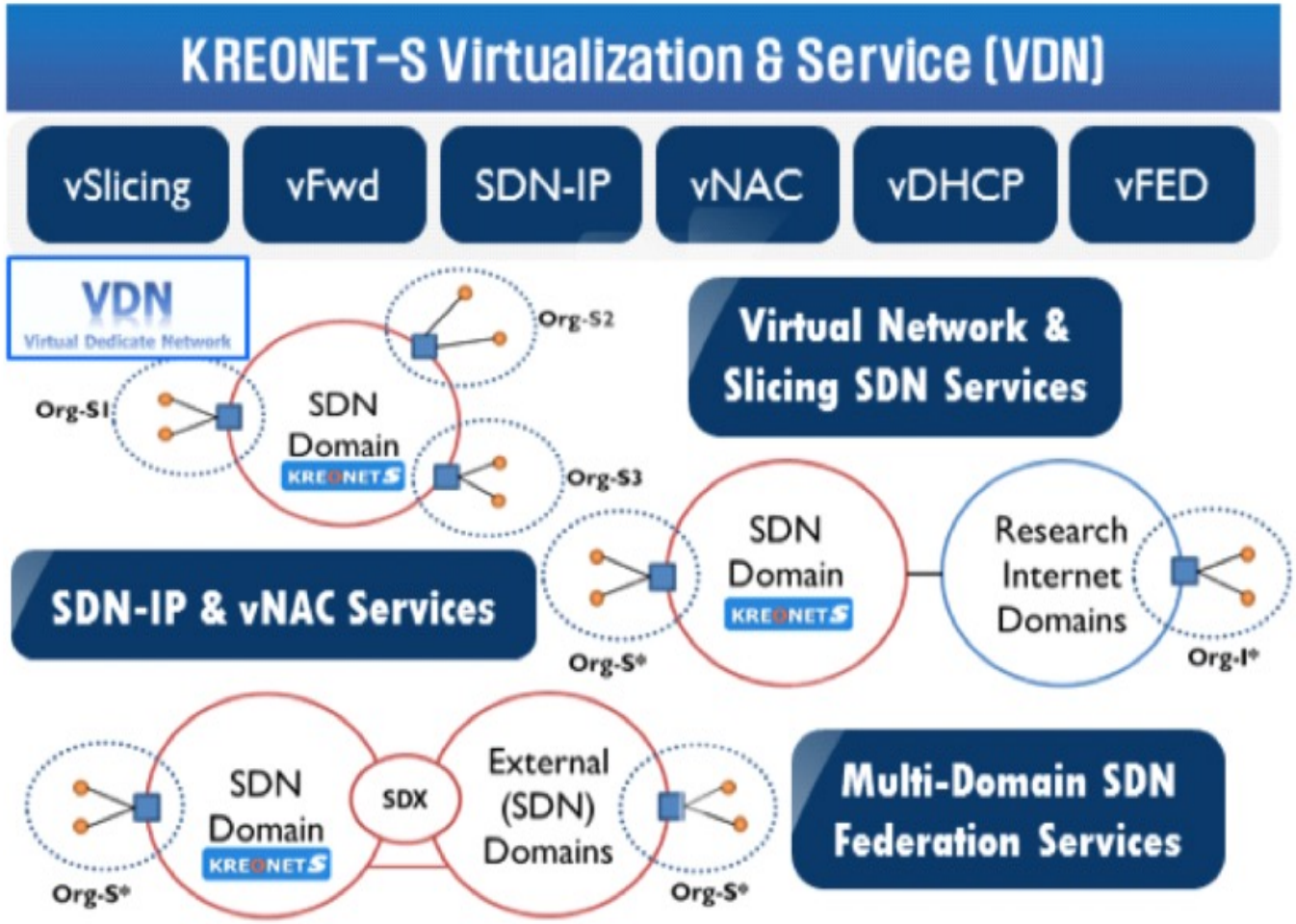
- Container-based Computing and Storage Resource Management System using Kubernetes Cluster and Ceph Storage
- Easy and Integrated Log-in Facility based on KAFE (Korea Access Federation) - ID Federation Capability
- Private Image Repository Configurations using Open-source Software (e.g., Harbor)



KREONET N-S-C Orchestration System (3)

2) VDN Management Module for Network Slicing w/ Computing and Storage Resources

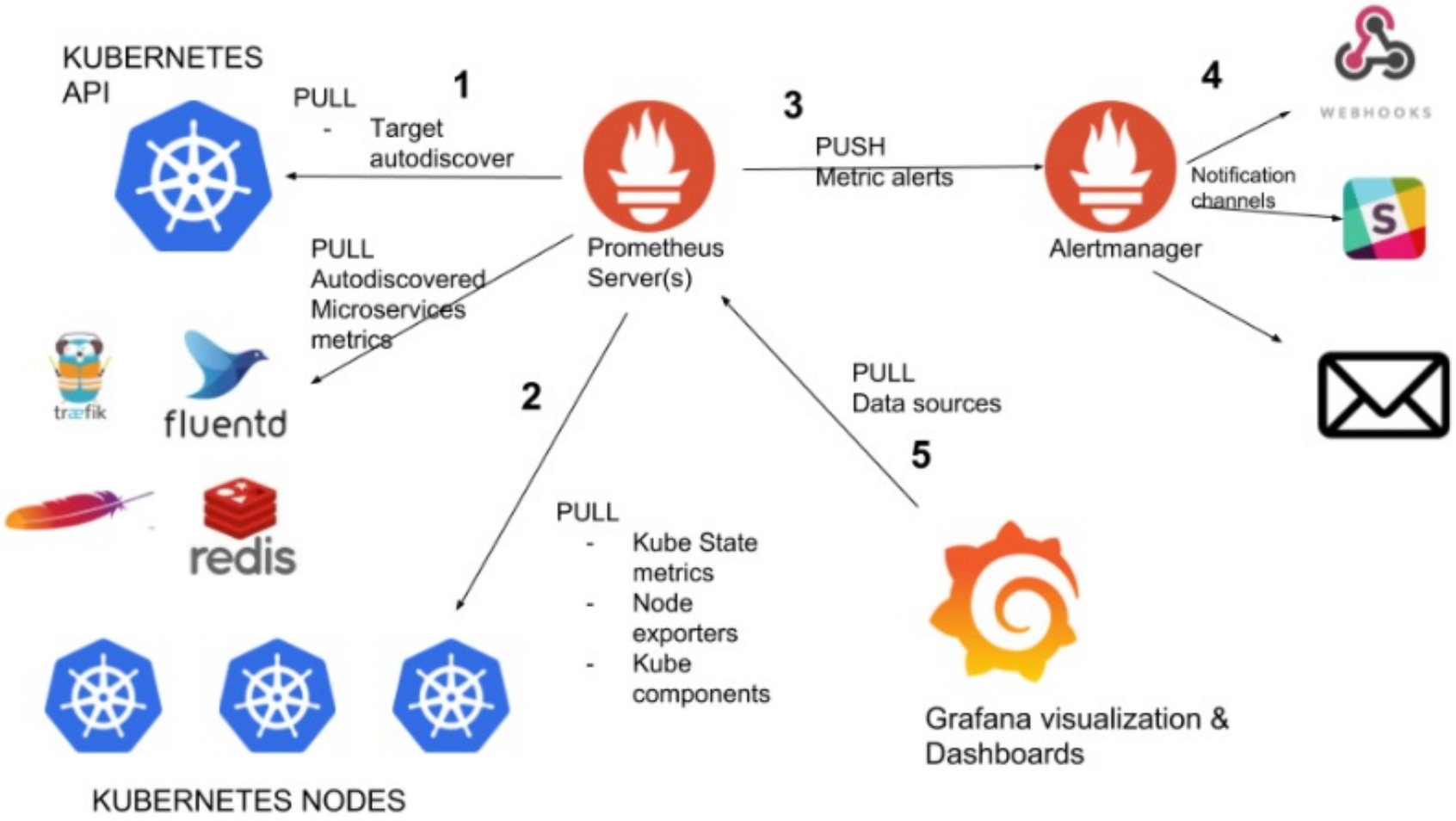
- Virtual Dedicated Network Management System which interacts with Computing and Storage Resources
- Container (k8s) Auto-Selection and Provisioning based on VDN-CNI and Location-oriented Algorithms
- VDN Create, Update, and Delete Operations for Administrators



KREONET N-S-C Orchestration System (4)

3) Monitoring & Visualization Module

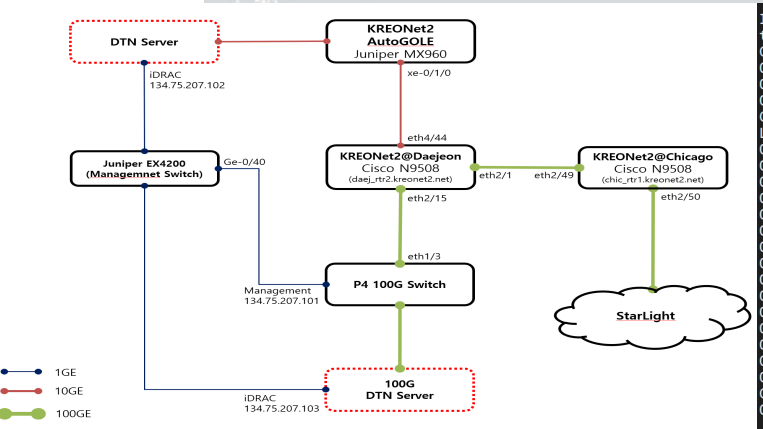
- Individual Resource (Compute, Memory, Disk, etc.) Monitoring System coupled with k8s using Prometheus and Grafana
- System Log (Warnings and Errors) Collection System using Fluentd and ELK (Elasticsearch, Logstash, Kibana), etc.



KREONET P4 Testbed

Objectives:

- Integrate the KISTI P4 switch into the global RARE network
- Provide a P4 routing platform and a global testbed for experimentation and testing of solutions to address issues in the R&E landscape
- Improve visibility of control plane metrics by allowing quick creation of instances from the NMaaS platform

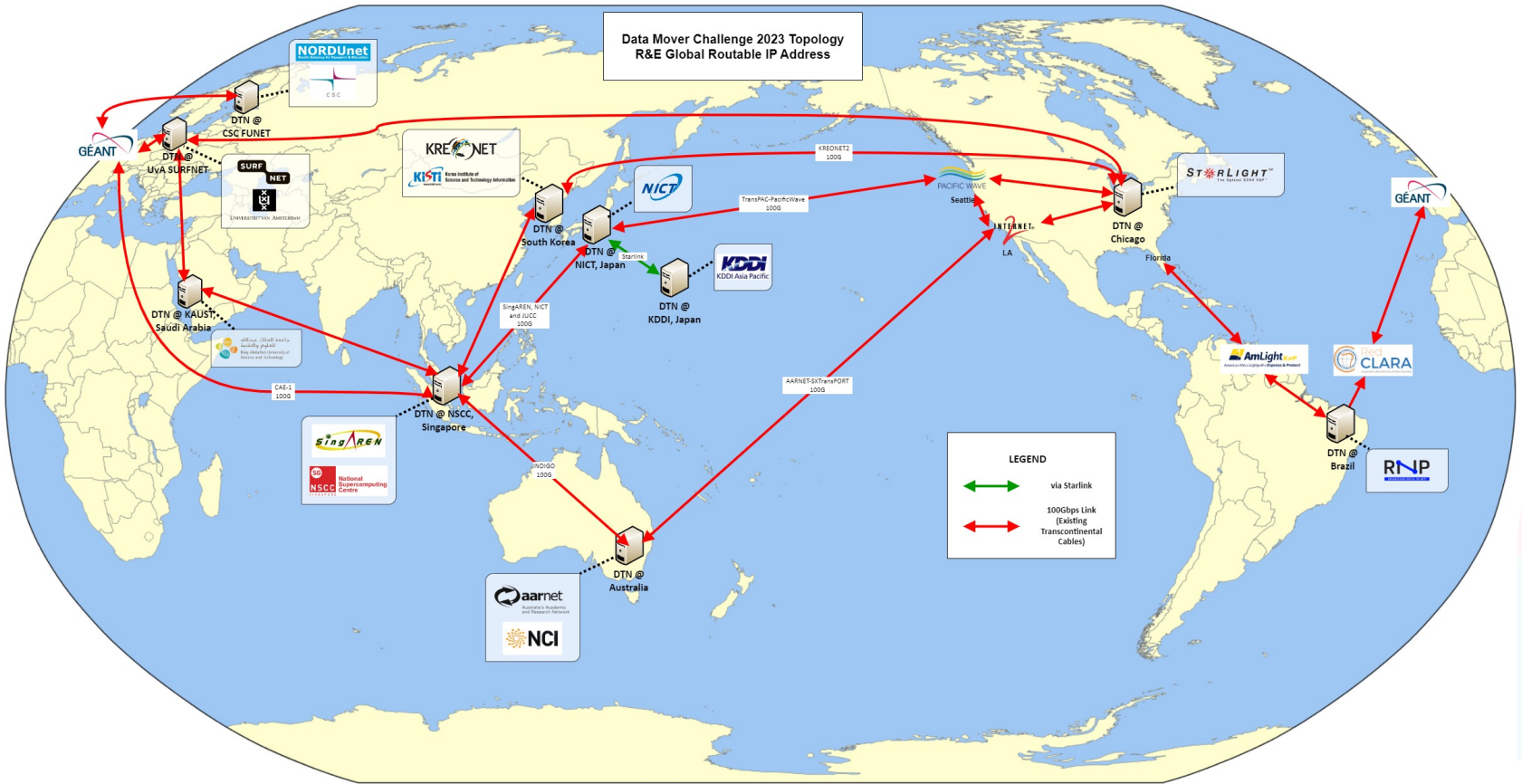



```
ICN0001#show ipv4 route CORE
typ  prefix          metric   iface      hop        time
C    0.0.0.0/32      0/0      template1  null       1d16h
O    10.0.8.0/31     110/371  sdn1.1237  10.1.24.1  00:00:51
O    10.0.16.0/31    110/499  sdn1.1237  10.1.24.1  00:00:51
O    10.1.1.1/32     110/275  sdn1.1237  10.1.24.1  00:00:51
C    10.1.24.0/24    0/0      sdn1.1237  null       1d16h
LOC  10.1.24.24/32   0/1      sdn1.1237  null       6d21h
O    10.2.2.2/32     110/282  sdn1.1237  10.1.24.1  00:00:51
O    10.3.3.3/32     110/298  sdn1.1237  10.1.24.1  00:00:51
O    10.4.4.4/32     110/298  sdn1.1237  10.1.24.1  00:00:51
O    10.5.5.5/32     110/308  sdn1.1237  10.1.24.1  00:00:51
O    10.6.6.6/32     110/290  sdn1.1237  10.1.24.1  00:00:04
O    10.7.7.7/32     110/291  sdn1.1237  10.1.24.1  00:00:51
O    10.8.8.8/32     110/371  sdn1.1237  10.1.24.1  00:00:51
O    10.9.9.9/32     110/292  sdn1.1237  10.1.24.1  00:00:51
O    10.10.10.10/32  110/290  sdn1.1237  10.1.24.1  00:00:51
O    10.11.11.11/32  110/508  sdn1.1237  10.1.24.1  00:00:04
O    10.12.12.12/32  110/308  sdn1.1237  10.1.24.1  00:00:51
O    10.13.13.13/32  110/292  sdn1.1237  10.1.24.1  00:00:51
O    10.15.15.15/32  110/402  sdn1.1237  10.1.24.1  00:00:51
O    10.16.16.16/32  110/499  sdn1.1237  10.1.24.1  00:00:51
O    10.18.18.18/32  110/293  sdn1.1237  10.1.24.1  00:00:51
C    10.24.24.24/32  0/0      loopback0  null       25d21h
O    10.99.99.99/32  110/300  sdn1.1237  10.1.24.1  00:00:51
```

SCA Data Mover Challenge

Objectives:

- A competition that is run once every 2 years and it aims to **bring together experts from industry and academia in a bid to test their software and solutions for transferring huge amounts of research data**.
- Optimising point-to-point data transfers between sites
- Showcase challengers by having them compete in deploying the **best software tools on Data Transfer Nodes** (DTNs) that are set up within current international Research and Education Networks across the globe.
- To bring together a community of experts in DTN deployments and operations

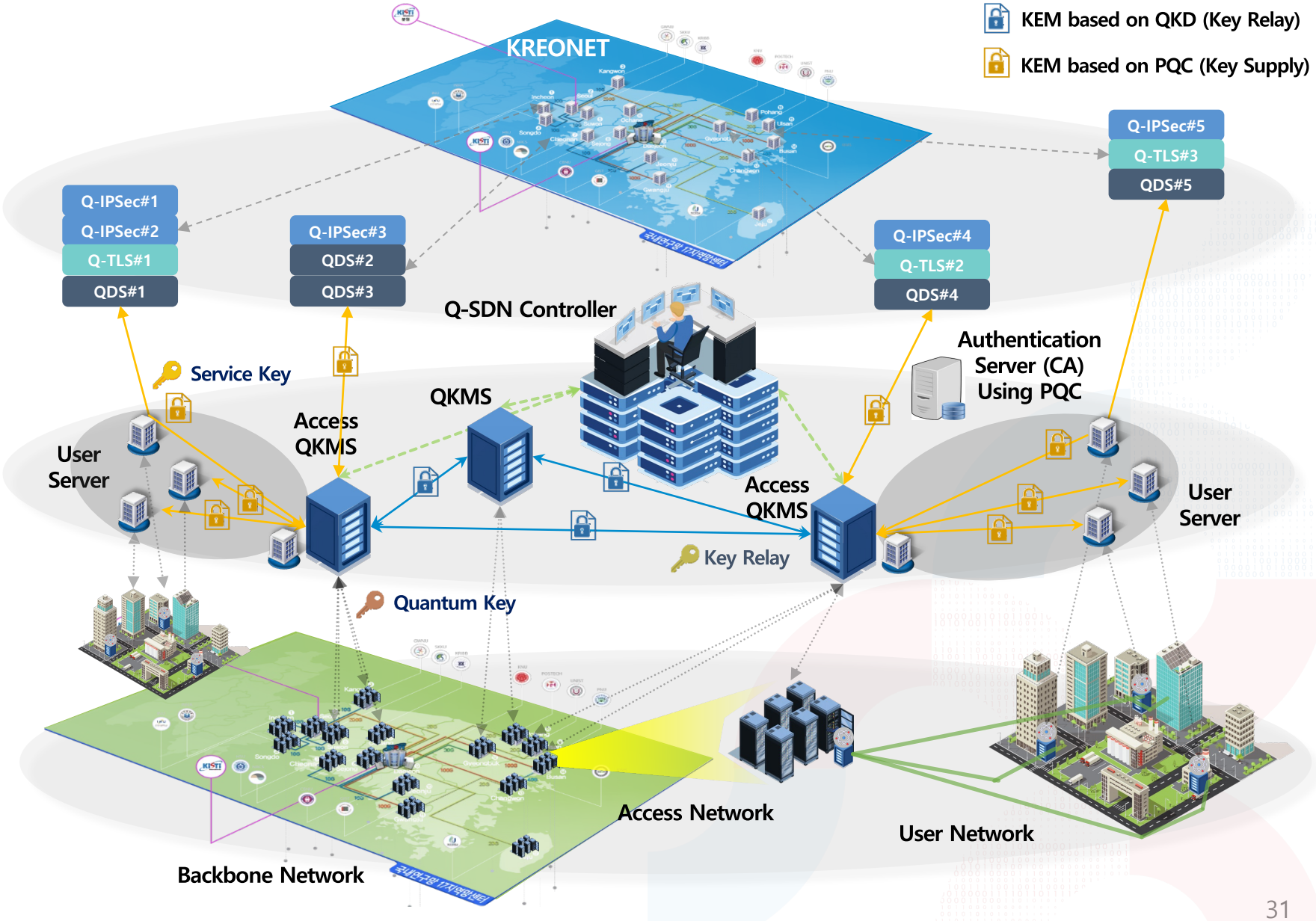


<Network Partners>

<DTN Partners>

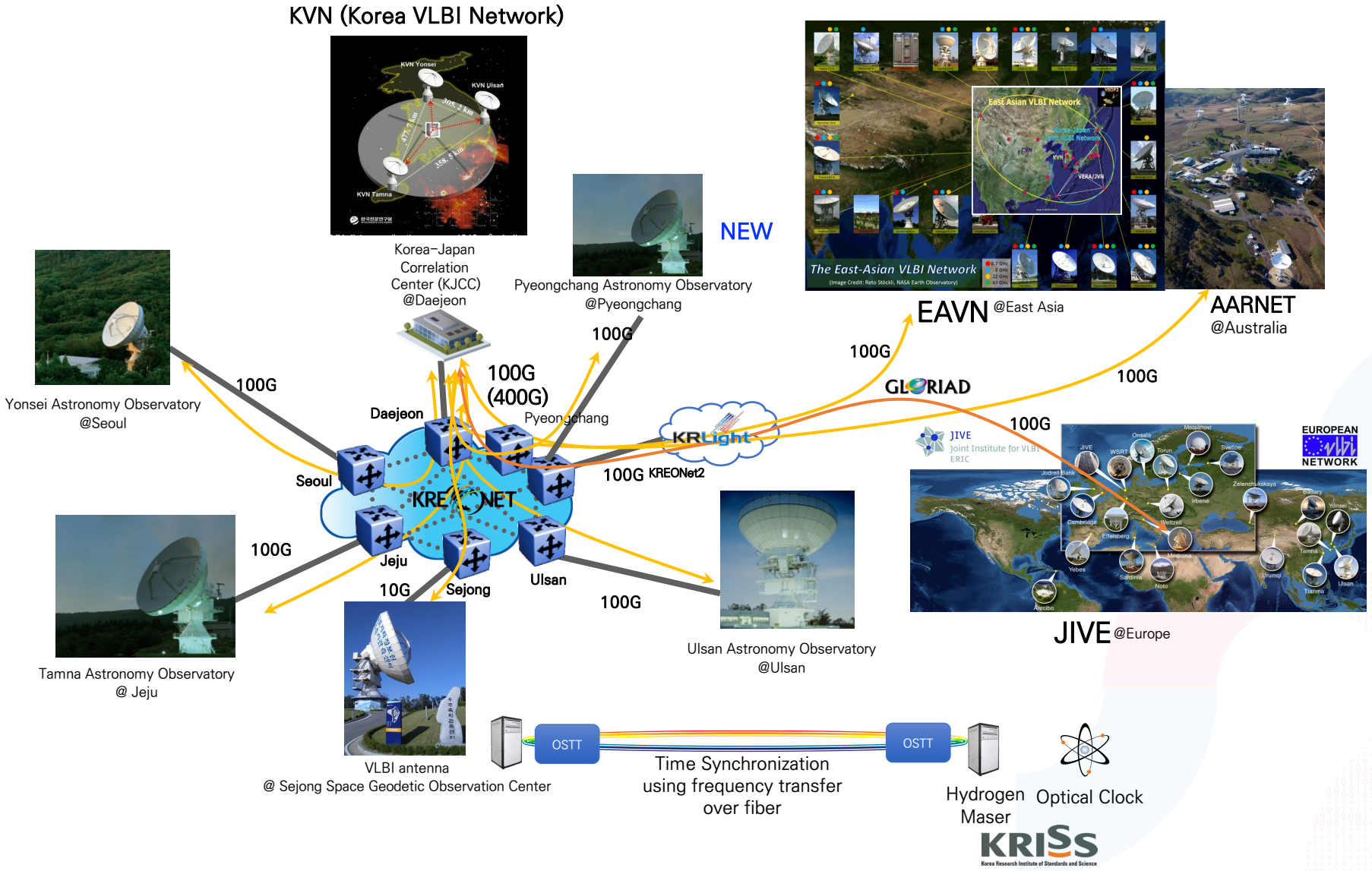
❑ QKD system for KREONET

- Enhancing the security of KREONET through preemptive action against quantum computers
- QKD system for backbone network
  - Long-distance QKD system development
- QKD system for access network
  - Multiplexable QKD system with reasonably sized receiving end
- Networkization of QKD system
  - Reduction of cost, complexity, and operational difficulty of QKD system



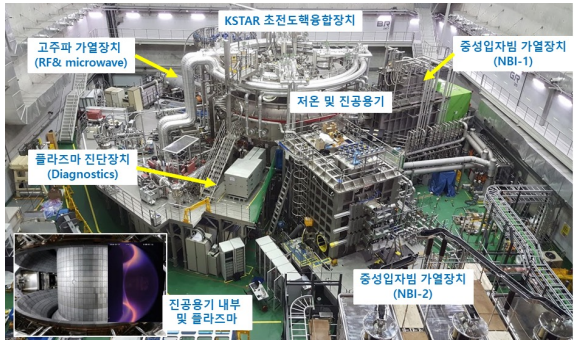
Korea VLBI Network (KVN) over KREONET/KREONet2

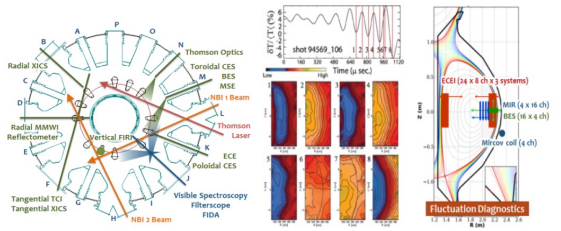
VLBI : Very Long Baseline Interferometry



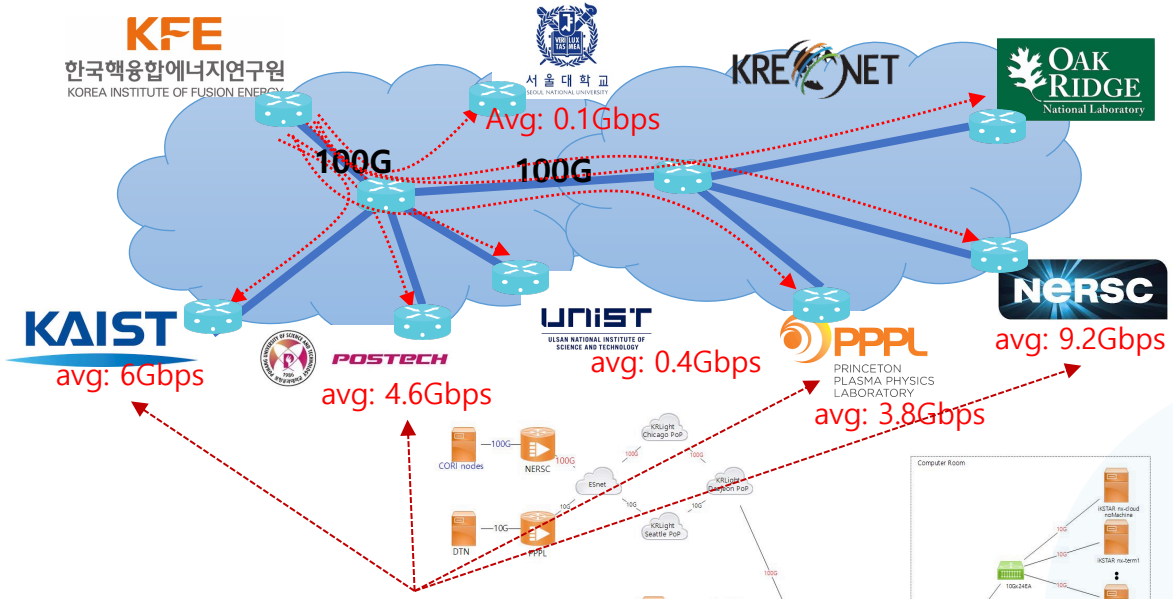
KSTAR over KREONET/KREONet2

KSTAR: Korea Superconducting Tokamak Advanced Research

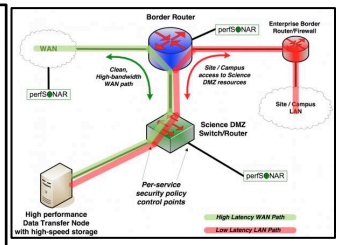


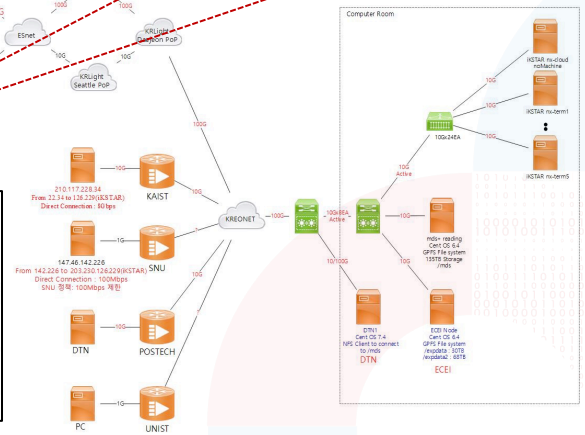


5GB Data per Shot



ScienceDMZ Architecture





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https://doi.org/10.1080/15361055.2020.1851073
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A Framework for International Collaboration on ITER Using Large-Scale Data Transfer to Enable Near-Real-Time Analysis

R. M. Churchill [a], C. S. Chang [a], J. Choi [b], R. Wang [b], S. Klasky [b], R. Kube [a], H. Park [c], M. J. Choi [d], J. S. Park [d], M. Wolf [b], R. Hager [a], S. Ku [a], S. Kampel [a], T. Carroll [a], K. Silber [a], E. Dart [e], and B. S. Cho [f]

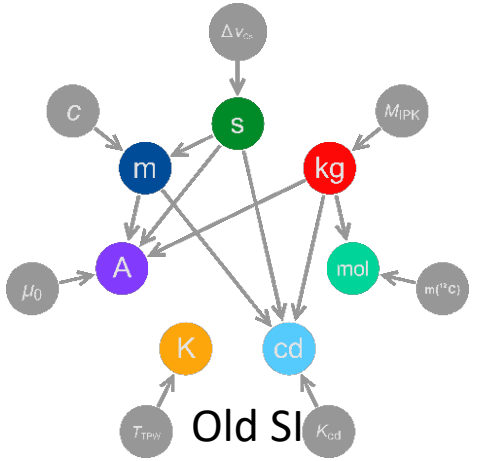
[a] Princeton Plasma Physics Laboratory, Princeton, New Jersey 08540 [b] Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830 [c] Ulsan National Institute of Science and Technology, Ulsan 689-798, Korea [d] National Fusion Research Institute, Daejeon 34133, Korea [e] Energy Sciences Network, Lawrence Berkeley National Laboratory, Berkeley, California 94720 [f] KREONET Operation and Service, Korea Institute of Science and Technology Information, Daejeon 305806, Korea

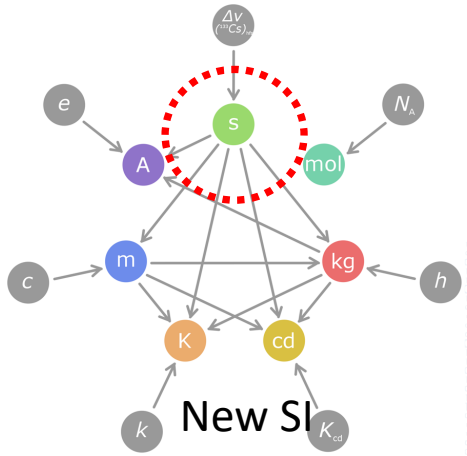
New SI and Optical Clock

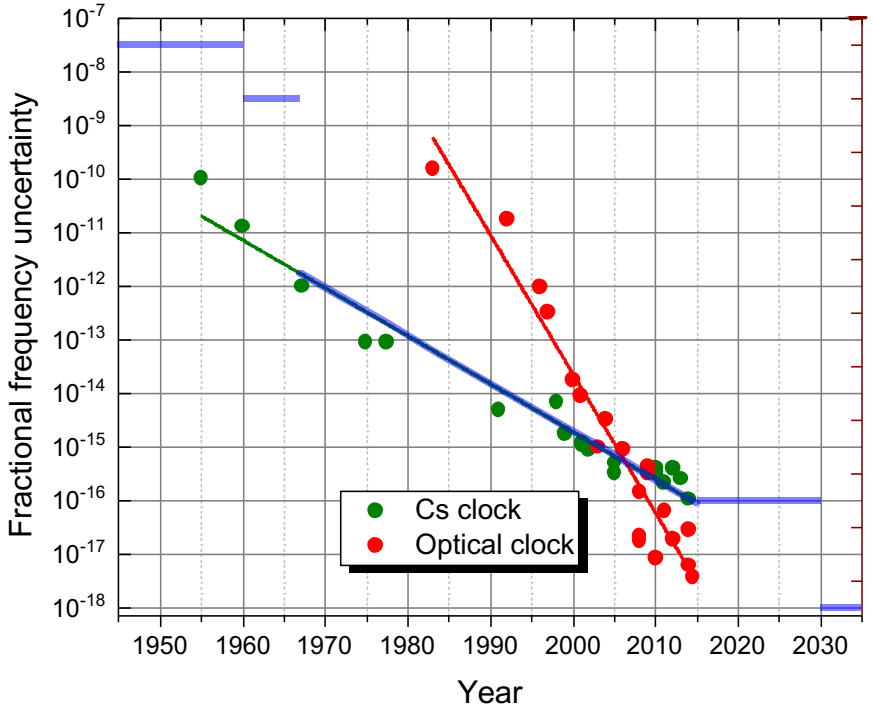
"Never measure anything but frequency!"

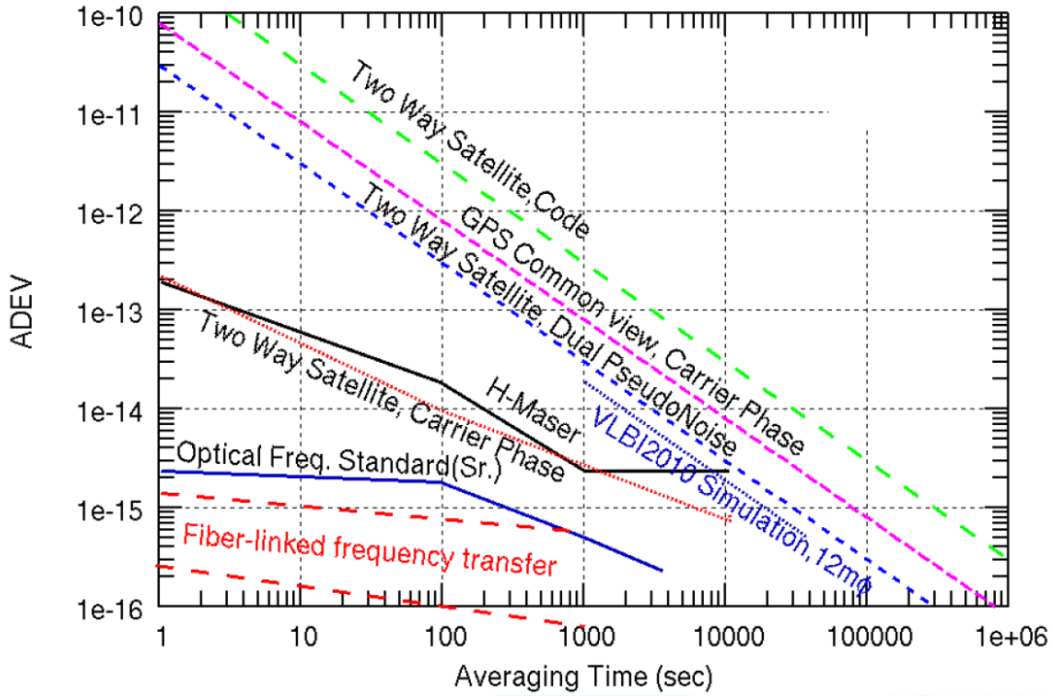
-- Arthur Schawlow

(1981 Nobel prize in Physics)

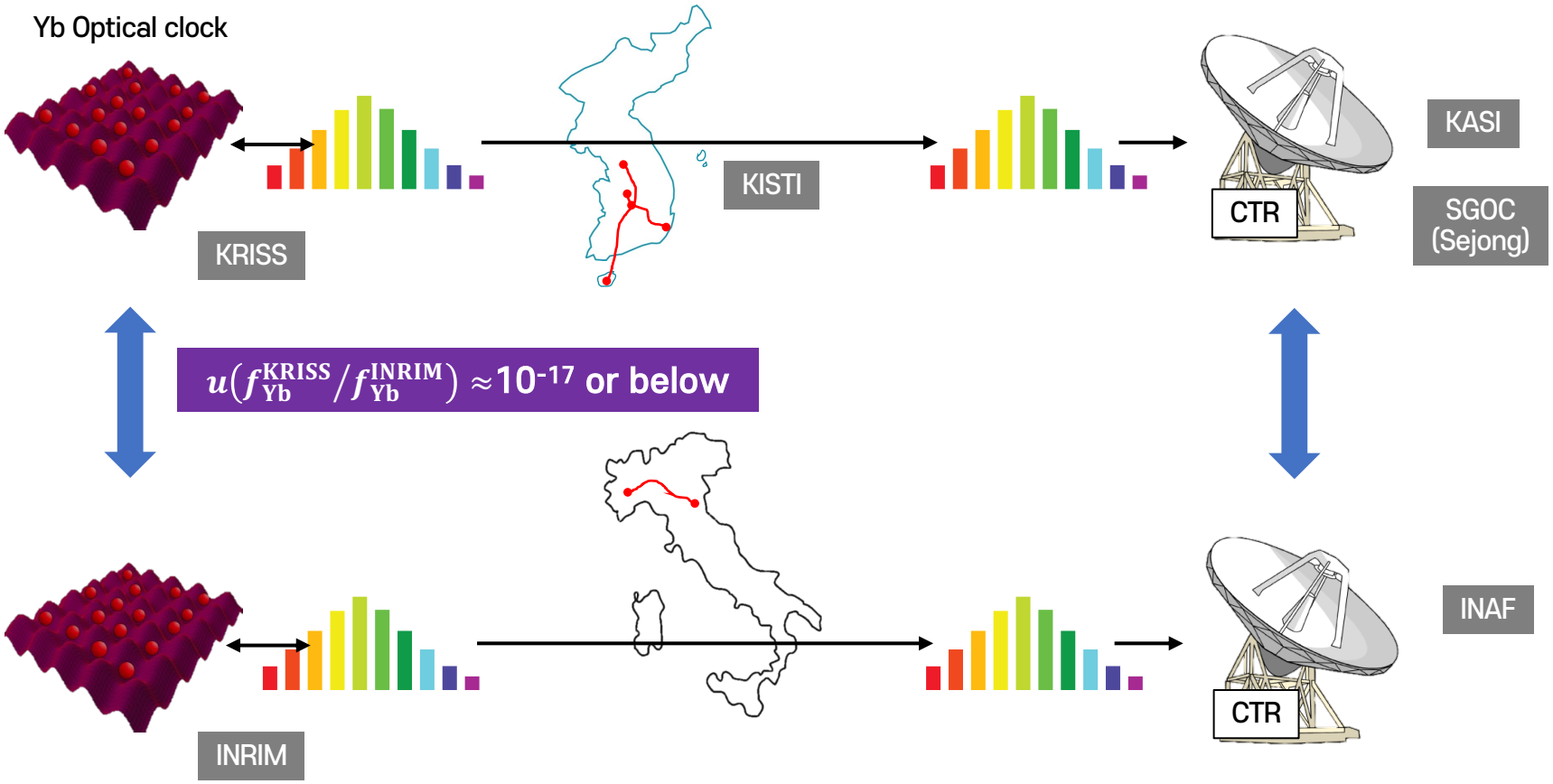








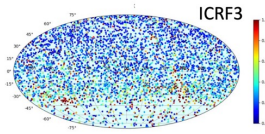
Inter-continental optical clock comparison using broadband VLBI



	KOREA	ITALY
Optical clock	Yb, running	Yb/Sr, running
Fiber link	KRISS – KISTI – KVN (except Jeju)	INRIM – Medicina
Transferred frequency	RF (OSTT, PikTime) CW laser f-comb @ Sejong or KVN	CW laser f-comb @ Medicina
VLBI	22/43/86 GHz @ Sejong 22/43/86 GHz @ KVN	22/43/86 GHz @ Medicina

CTR : Compact Triple-band Receiver (K,Q, W band)

Inter-continental optical clock comparison using broadband VLBI



ICRF3 : The 3rd realization of the International Celestial Reference Frame

KOREA

Source (Star)

KRISS

GPS satelite

Optical Clock

Optical Comb

ITALY

KASI

ngii

INAF IRA

Standard Frequency Generator

CTR

KiSTi

KREONET

Standard Frequency Generator

Standard Frequency Generator

CTR

CTR

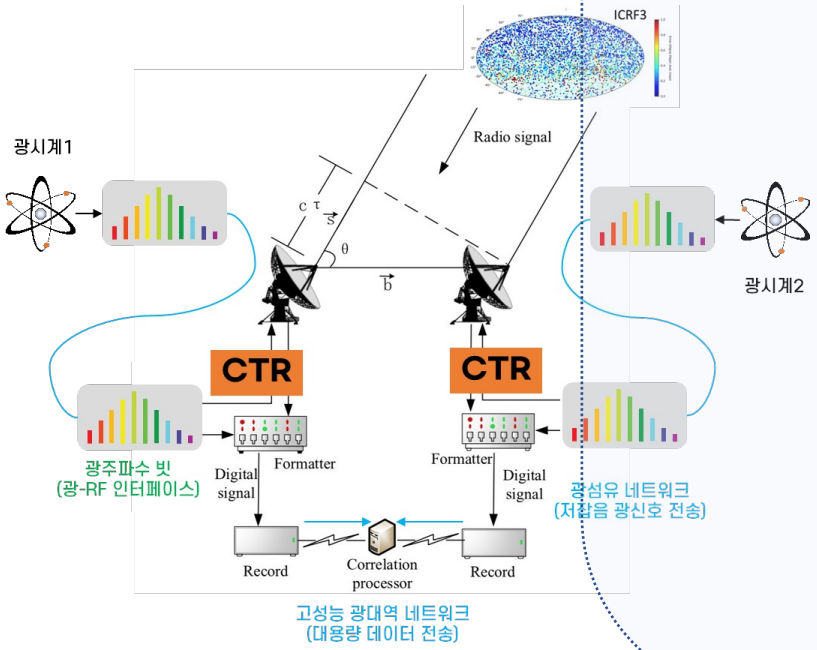
CTR

KAIST

Correlator

INRiM

ISTITUTO NAZIONALE DI RICERCA METROLOGICA



Summary

KREONET, the national science and research network of Korea

- **world-class national science and research network backbone**
- Collaborate with global research network for enhancing reliability of global network and demonstrating new network technology and service
- Develop advanced network and application service that meets user requirements of the big Science

LHCOPN & LHCONE

- LHCOPN, dedicate network to transport of WLCG traffic between the Tier 0 and the Tier 1
  - Upgraded to 100G/400G and more
- LHCONE, L3VPN, private network to provide a collection of access locations, LHC T1/2/3 sites
  - Scientific Network Tags (Scitags) is an initiative promoting identification of the science domains and their high-level activities at the network level
  - ”multiONE” with BGP communities, Each site joins only the VPNs of the groups it is collaborating with (e.g. ATLAS-ONE, CMS-ONE, DUNE-ONE, BelleII-ONE...)
  - KREONET LHCONE allows transit, if requested

S&T Infra,
Changing the world with Data KiSTi

Thank you

Buseung Cho (bscho@kisti.re.kr)